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Entomology Vol 5

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 58.

L. O. HOWARD, Entomologist and Chief of Bureau.

SOME INSECTS INJURIOUS TO FORESTS.

I. THE LOCUST BORER.

By A. D. HOPKINS, *In Charge of Forest Insect Investigations.*

II. THE WESTERN PINE-DESTROYING BARKBEETLE.

By J. L. WEBB, *Special Field Agent, Forest Insect Investigations.*

III. ADDITIONAL DATA ON THE LOCUST BORER.

By A. D. HOPKINS, *In Charge of Forest Insect Investigations.*

IV. THE SOUTHERN PINE SAWYER.

By J. L. WEBB, M. S., *Agent and Expert.*

V. INSECT DEPREDATIONS IN NORTH AMERICAN FORESTS AND PRACTICAL METHODS OF PREVENTION AND CONTROL.

By A. D. HOPKINS, PH. D., *In Charge of Forest Insect Investigations.*

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FOREST INSECT INVESTIGATIONS.

A. D. Hopkins, *in charge.*

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[a] Transferred to another branch of the bureau.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., August 5, 1910.

Sir: I have the honor to transmit herewith, for publication as Bulletin No. 58, five papers dealing with insects injurious to forests and forest products. These papers were issued separately during the years 1906 to 1909.

Part I, "The Locust Borer," by A. D. Hopkins, comprises a summary of information from published accounts, supplemented by data secured by recent investigations, and deals more particularly with practical methods for controlling this, our most important enemy of the black locust. It is designed to be of service to owners of plantations and forests, as well as to investigators, in the prevention of injuries to this useful tree.

Part II, "The Western Pine-destroying Barkbeetle," by J. L. Webb, has special reference to the results of investigations by Mr. Webb in central Idaho in 1905, but relates also to the results of other investigations and to available information on the insect and methods of controlling it.

Part III, "Additional Data on the Locust Borer," by A. D. Hopkins, comprises a partial revision of Part I and gives additional information based on the results of investigations carried on since that part was issued.

Part IV, "The Southern Pine Sawyer," by J. L. Webb, gives the results of special investigations by Mr. Webb and relates to a subject of much economic importance to the timber interests of the Southern States, and especially of sections in which the pine timber is damaged by storms. The results of these investigations and the information contained in this paper make it possible to avoid a large percentage of the losses from damage by the sawyer, which have heretofore seemed inevitable.

Part V, "Insect Depredations in North American Forests and Practical Methods of Prevention and Control," by A. D. Hopkins, gives a summary of facts, conclusions, and estimates relating to the forest-insect problem as applied to North American conditions and calls attention to its importance in the future management of private, state, and national forests. The matter is presented in as brief and concise a form as possible, in order that the information may be readily available to the general reader, as well as to the forester and student, and references are made to publications in which more detailed accounts may be found. The statements and conclusions relating to the insects and their work and to methods for their control are based almost entirely on investigations and observations by Doctor Hopkins and by assistants in the Bureau of Entomology working under his direction, carried on in all of the principal forest areas of the United States.

Respectfully,

L. O. HOWARD,
Entomologist and Chief of Bureau.

Hon. W. M. HAYS,
Acting Secretary of Agriculture.

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[a] The five papers constituting this bulletin were issued in separate form on June 13 and August 18, 1906; March 5, 1907; and November 10 and December 4, 1909, respectively.

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U. S. D. A., B. E. Bul. 58, Part I. F. I. I., June 13, 1906.

SOME INSECTS INJURIOUS TO FORESTS.

THE LOCUST BORER.

(*Cyllene robiniæ* Forst.)[a]

By A. D. Hopkins,

In Charge of Forest Insect Investigations.

OBJECT OF PAPER.

The object of this paper is to give a summary of the more important published information, supplemented by recently determined new facts relating to the locust borer and methods of controlling it, which will be of service to the investigator in the determination of additional facts, and to the owners of plantations and forests in suggesting methods of preventing losses.

ECONOMIC IMPORTANCE OF THE INSECT.

The economic importance of the well-known locust borer as affecting the growth of the black locust or yellow locust (*Robinia pseudacacia*) is fully realized by everyone who is interested in this valuble forest and shade tree, and the urgent need of additional information on the subject is indicated by the frequent inquiries of correspondents and by the recent articles in newspapers, journals, and special publications which have been called forth by the proposed extensive commercial planting of the locust by railroad and other companies and by individuals.

INVESTIGATIONS.

In connection with the general study of insects injurious to forest trees, the locust borer has received considerable attention by the writer since 1890.[b] In March, 1905, a plan of cooperation between the

---

[a] Order Coleoptera, Family Cerambycidæ.

[b] From 1890 to 1892 for the West Virginia Experiment Station, and since 1902 for the U. S. Department of Agriculture.

Bureau of Entomology and the Forest Service in the investigation of insect enemies of the black locust was proposed and adopted, by which the subject is receiving special attention from the viewpoint of both the forester and the entomologist, with the primary object of practical results.

CHARACTER OF THE INSECT AND ITS WORK.

The locust borer is a whitish, elongate, so-called "round-headed" grub or larva (fig. 1), which hatches from an egg (fig. 2) deposited by a black or brown and yellow striped long-horned winged beetle (fig. 3) found on the trees and on the flowers of golden-rod from August to October. The eggs are deposited in the crevices of the bark of living, growing trees from August to October, and the young borers (fig. 2, *b*, *c*) hatching therefrom mine into the outer portion of the living inner bark (fig. 5), where they pass the winter, and in the spring bore through the bark into the sapwood and heartwood. Here they transform in July and August to pupæ (fig. 4) and in August and September to adult beetles, which soon emerge from the trees and deposit eggs for the next annual generation of borers and beetles.

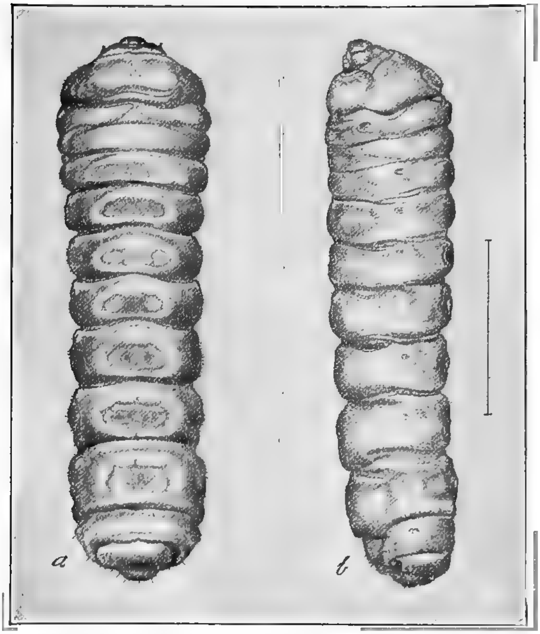
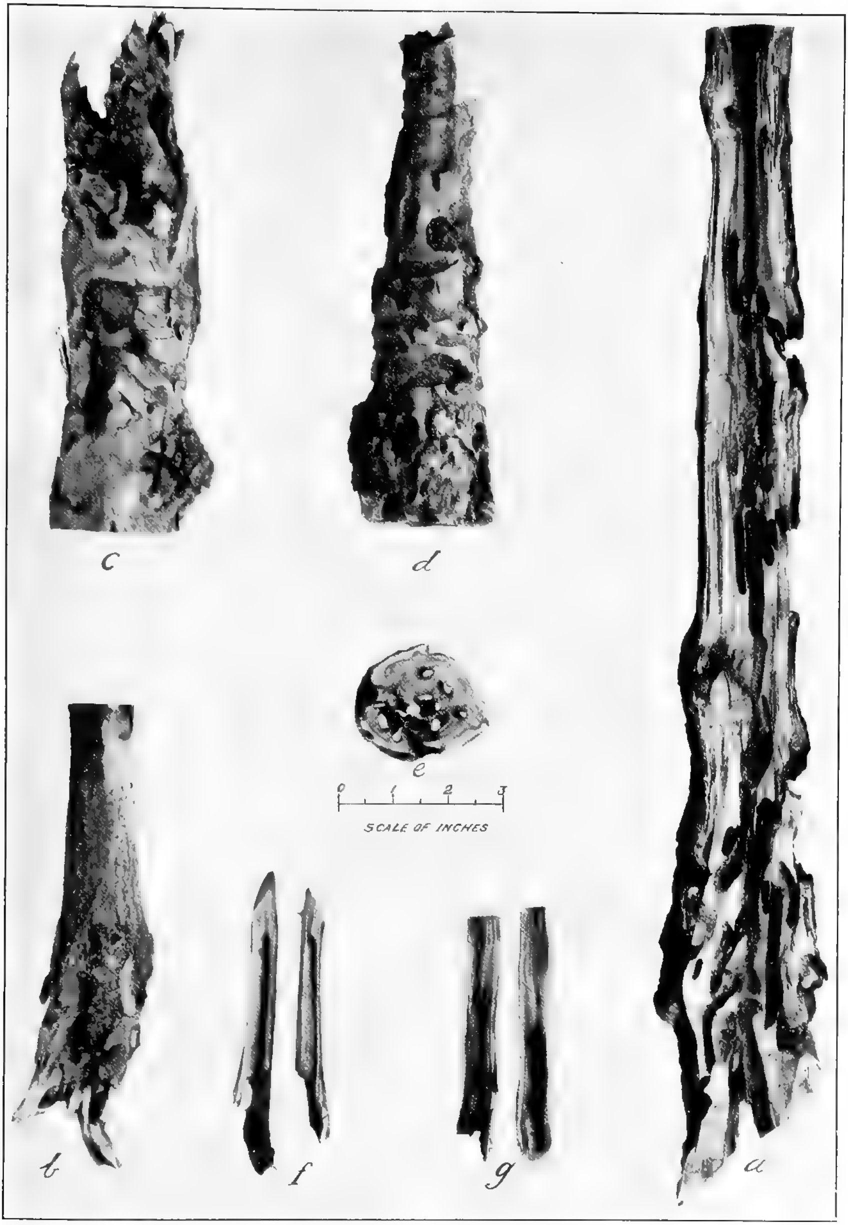


FIG. 1.—The locust borer (*Cyllene robiniæ*): *a*, larva, dorsal view; *b*, same, lateral view. Line at right represents natural length (original). The larva in profile should show minute prothoracic feet.

The injury to the trees (Pl. I) consists of wounds in the bark and sapwood which, if sufficiently severe or repeated year after year, result in either a stunted worthless growth or the death of young and old trees, while the numerous worm holes in the wood reduce its commercial value or render it worthless.

The presence of the insect in injurious numbers is indicated (1) by the frequency of the adults on the golden-rod flowers and on the trees, from August to October; (2) by the slight flow of sap and by the brownish borings where the young larvæ are at work in the bark, during April and May; (3) by the whitish sawdust borings lodged in



WORK OF THE LOCUST BORER.

a, Section of young tree 3 inches in diameter; *b*, section of young tree 2 inches in diameter, which was broken off near surface of ground; *c*, *d*, section of branch from badly damaged tree, showing healing wounds in surface of wood; *e*, transverse section of same; *f*, *g*, sections of branches one-half inch in diameter or less, showing in each the total length of burrow in which a larva developed and transformed to the adult beetle. (Original.)

the rough bark, in the forks of the tree, and on the ground around the base of the trunk, during May, June, and July; (4) by the breaking down of the branches and young trees, and by the sickly appearance of the young twigs and leaves in July and August.

This insect appears to be present and more or less injurious in all of that part of the United States which is east of the Great Plains and north of the Gulf States. Published information and reports of forest officials and others indicate that in Oklahoma and Indian Territory and west of the Great Plains the locust is now quite free from injury by the borer; but that these regions will remain exempt is by no means certain.

EXTENT OF DAMAGE OR LOSS.

So extensive is the damage to natural growth, artificial plantations, and shade trees that in some sections within the natural range of the tree in the Eastern States, but particularly in the Middle West, where both the tree and the insect have been introduced, it is considered unprofitable to grow the tree for shade or timber, and in such sections the natural sprout growth is often considered a pest rather than otherwise.

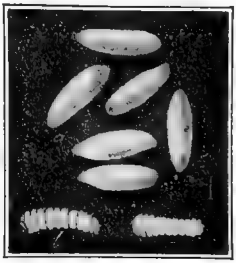


FIG. 2.—The locust borer (*Cyllene robiniæ*): *a*, eggs; *b*, *c*, larvæ from hibernation cells. Much enlarged (original).

The loss resulting from defective timber, stunted growth, and the death of trees is represented by the difference in value between the damaged growth or product and the same if uninjured and healthy. This, if expressed in dollars, would represent a large sum.

POSSIBILITIES OF PREVENTING LOSSES.

There are sections, especially in the natural home of the tree, where, as has been frequently observed by the writer and others, the damage is not sufficiently severe to seriously affect the vitality of the trees or the commercial value of the product; and our present knowledge of the insect and of methods of preventing losses from its ravages indicates that in properly selected localities, and under proper forestry methods of management, the tree, so far as this insect is concerned, can be grown successfully on an extensive scale, and can be made to yield most satisfactory returns.

HISTORICAL REFERENCES.

The first reference to this insect, according to Fitch, is a figure and description by Pitiver in his Gozophylacium, published in London in 1702. Drury figured it in 1770, and the following year, 1771, Forster gave it the specific name of *robiniæ*, under which it is at present recognized. It has been referred to many different genera, but is now recognized as belonging to the genus Cyllene. Both Drury and Forster received it from the "Province of New York," and referred to it as inhabiting the locust tree (*Robinia pseudacacia*). It is therefore evidently an American species.

Some of the principal writers who have contributed important facts on the life history, habits, distribution, and remedies are: Dearborn, 1821; Harris, 1826–1841; Fitch, 1858–1863; Walsh, 1865–1867; Riley, 1867; Lintner, 1890; Schwarz, 1890; the writer, 1891–1898; Felt, 1901–1905; Cotton, 1905; White, 1906, and others. (See list of publications, p. 15.)

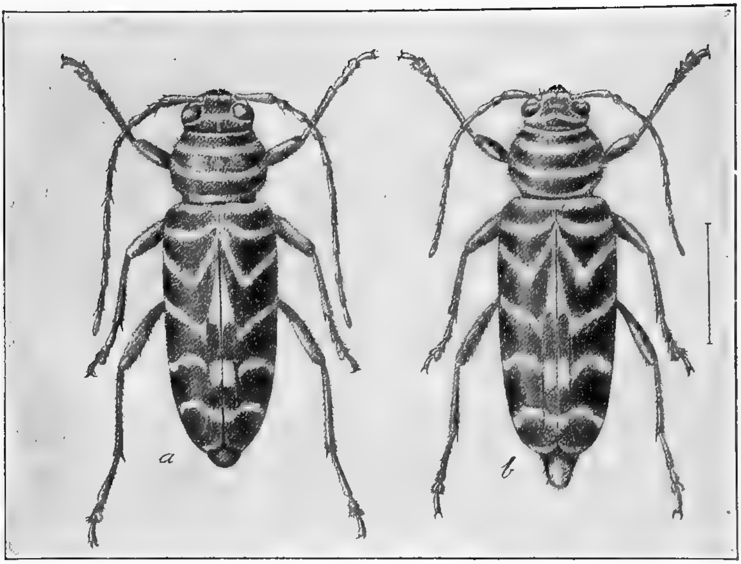


FIG. 3.—The locust borer (*Cyllene robiniæ*): *a*, male beetle; *b*, female beetle. Much enlarged (original).

REVIEW OF PUBLISHED DATA.

Gen. H. A. S. Dearborn was the first to record the more important facts in the life history and habits of the insect. Indeed, so complete and accurate were his observations that comparatively little has been added by subsequent writers, who have extensively quoted and repeated them. He found the beetles on the trunks of trees from the 1st to the 25th of September, the females depositing their "snow white" eggs in the crevices of the bark, four to nine in each place. These eggs hatched before cold weather, and "the young larvæ just buried themselves in the tender inner bark," where they remained until about the 1st of April, when they commenced boring, and soon passed into the solid wood. He stated that it could always be ascertained when and where the borers were at work by the oozing of sap from the wounds made by them. By the 20th of July the larvæ attained their full size, by the 28th some of them changed to pupæ, and the perfect insects were on the trees September 3. These observations were made on his grounds near Roxbury, Mass., during several years previous to 1821, when they were reported in a letter to John Lowell, and published, together with an account of his unsuccessful experiments with whitewash, mortar, and plaster, in the Massachusetts Agricultural Journal, Volume VI, 1821, pages 270–275.

Col. T. Pickering, in a letter to Mr. Lowell the same year and published in the same volume, stated that there were trees in New Hampshire uninjured by the borer, as well as in some of the Southern States; that he had observed the stems of young trees in Washington, D. C., infested, while in Georgetown (D.C.) he saw large thrifty trees uninjured; and he concluded that natural growth in groves was much less liable to injury than transplanted growth.

Fitch, writing in 1858, stated that numbers of specimens were sent to him year after year from Indian Territory.

Schwarz (1890) observed that in and around the District of Columbia the insect lives in large colonies, affecting all trees of small groves, while long hillsides full of locust are not infested.

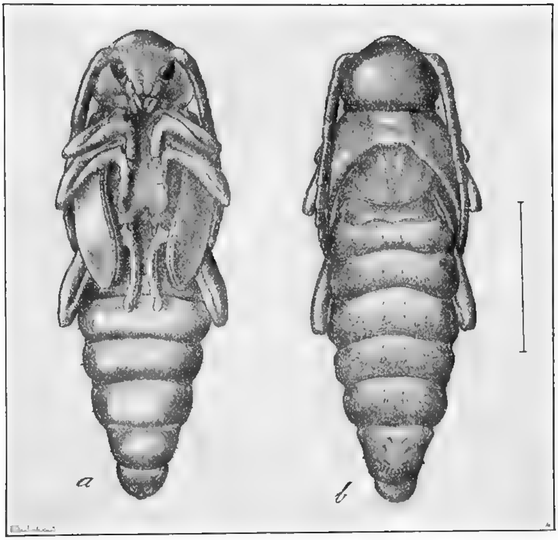


FIG. 4.—The locust borer (*Cyllene robiniæ*): *a*, pupa, ventral view; *b*, same, dorsal view. Much enlarged (original).

R. S. Kellogg, in his discussion of forest planting in western Kansas, says:[a]

> By locating plantation on good ground and giving it first-class care, the trees will reach fence-post size before the borers do much damage. They should then be cut and utilized. The rapid sprout growth will soon make a new crop. A stump sprout sometimes attains a height of 10 feet the first season. Handled in this manner, black locust can be profitably raised in many places where it is altogether unsuited for a permanent tree.
>
> At present borers are a menace to black locust trees throughout western Kansas and Nebraska, though there are occasional local areas that are not affected. They

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[a] Bul. 52, Bur. Forestry, U. S. Dept. Agric., 1904.

have so far done little damage in southwestern Kansas, but they are moving both southward and westward. They are abundant at Pratt, Kinsley, Dodge, and Scott, and are appearing at Medicine Lodge, Coldwater, Meade, and Garden City. Yet of the numberless trees that have been killed or seriously injured nearly all reached a size that could well be used for posts or stakes before succumbing. This shows that black locust may be successfully grown in commercial plantations if cut as soon as large enough for posts. * * *

Just south of the Kansas line, in Woods County, Okla., black locust grows remarkably well, and has not yet been molested by borers.

Cotton (1905) observed that in Ohio injury was greater in single trees and plantations of considerable size than in natural forests.

Dearborn found that whitewashing the trees in April and filling the holes with mortar in July was not entirely successful as a remedial measure, but he suggested cutting out and burning infested trees in April and protecting the young, thrifty trees. Harris suggested the collection of the beetles by children, and Fitch, the planting of goldenrod to attract the beetles, so that these could be collected and destroyed. Lintner suggested the application of soap solution and carbolic acid to prevent the beetles from depositing eggs, and the cutting out of young larvæ when their presence is indicated by sap and borings. Riley suggested destroying the young borers as soon as hatched. The writer recommended severe pruning in March, and clean culture was recommended by Felt.

The insect has been recorded from Canada southward to Pontchartrain, La., Texas, and Indian Territory, and westward into Nebraska.

Some of the records of destructive ravages are the following: Peck (1818), Harris (1826), in New England; Fitch (1858), in New York; Rogers, Reed, and Bethune (1855 to 1867), in Canada; Walsh (1866), in Illinois and Kansas; Laurent (1893), around Philadelphia; the writer (1891 to 1898), in West Virginia; Smith (1898), in New Jersey; Cotton (1905), in Ohio; White (1906), in the Mississippi Valley, about twenty years after extensive planting was begun by settlers.

REVISION OF PUBLISHED DATA.

Some of the published records relating to the insect which have been frequently quoted or repeated require, according to the writer's observations, some amendments and corrections.

It would appear that normally but a single egg is deposited in a place, rather than clusters of four to nine. The female does not pierce the bark or place her eggs in the cambium layer. The larvæ do not enter the sapwood before winter, but, as observed by Dearborn and verified by the writer, remain in the outer portion of the inner bark. Records of the insect infesting honey locust are probably due to the fact that the black locust is sometimes referred to under this name, which is the correct one for an entirely different tree. It appears now that its attack is confined entirely to Robinia. It is not necessary that a tree or branch should be some inches in diameter before it is damaged, for the writer has found full-grown larvæ in sprouts and branches less than one-half inch in diameter.

In the writer's opinion, all attempts to cultivate locust in the eastern United States *should not be abandoned* on account of the borer, although this has been recommended by some recent writers. It has been stated that the locust would probably not be injured by the borer in the southern limit of its range and in the country west of the Great Plains. While this may be true, precaution should be taken to prevent its introduction into such localities, since it is not improbable that if the insect be introduced and become established it may prove even more destructive there than in its natural home, as was demonstrated in the Mississippi Valley.

Nearly all methods heretofore recommended are subject to practical application to shade trees and small plantations only; therefore there is special need for suggestions of practical methods of combating the insect and preventing losses in large commercial plantations and in natural forest growth, and it is hoped that this paper will contribute something of value along this line.

OBSERVATIONS BY THE WRITER, 1890–1905.

Adults were collected on golden-rod flowers at Piedmont, Md., and Mineral County, W. Va., on August 25, 1890, and on golden-rod and locust leaves at Morgantown, W. Va., September 16 and 17, 1891. Young larvæ were found mining in living bark of trees at Kanawha Station, W. Va., May 1, 1891, and on May 20 the same larvæ had entered the wood, but a great many had died.

It was frequently noted that the locust in the forests of Chestnut Ridge in Monongalia and Pendleton counties, Laurel Hill in Preston County, and especially on Rich Mountain in Randolph County, W. Va., showed but slight damage by the borers. Similar observations were made in many other sections of the State, while in near-by and widely separated sections the damage was found to have been severe and continuous during the life of some of the older trees. In 1898 it was observed that badly damaged shade trees near Morgantown, W. Va., which had been severely pruned in March and April, had recovered, and the crowns were renewed by dense, vigorous, healthy growth, which suggested this method of treating badly damaged shade trees.

On October 9, 1904, it was found that the locust in the vicinity of Chevy Chase, Md., was but slightly damaged by the borer, although beetles were found in numbers on golden-rod and feeding on sap from wounds in bark of living sumac. This habit of feeding on sap is of special interest from the fact that it suggests the possibility of killing the beetles by means of a bait of some poisoned substance which would be attractive to them.

On May 23, 1905, it was found that the locust trees of all sizes in the open and in dense thickets along the old canal on Arlington Farm, Virginia, were thickly infested with the borers, which were all in the wood and ranged in size from quite small to nearly full grown. The ground around some of the trees in the open and on the borders of the groves was found to be covered with the sawdust borings to the depth, in some cases, of an inch or more, and the larvæ could be distinctly heard at work in the wood. Some of the young trees had been literally honeycombed and were broken off at the ground, others had many branches broken and hanging by the bark or fallen from the tree, and some other trees had the leaves turning yellow and dying, while one isolated tree in a field had failed to put forth leaves on some of the branches. Some infested branches cut on this date and placed in a box in the laboratory were found on July 12 to contain fully matured adults, and on July 20 they began to emerge, thus showing that the larvæ will complete their development in the wood after it is cut from the tree and becomes perfectly dry. Indeed, this record shows that the dry condition contributes to the rapid development of the insect, for on the same day (July 20) on which the beetles were found in the box, the trees from which the branches had been cut were examined and found to contain nothing but larvæ. Some more branches were cut on this date and placed in a tin can, where they were kept moist. The first beetles emerged from these on August 24, or more than thirty days after adults had emerged from the dry branch. On August 30 many adults had emerged. September 20 ten living adults and many dead ones were taken from the can, and on October 2 several more dead ones were removed.

When the trees were examined on July 20, a larva was found mining in a two-year-old branch less than one-half inch in diameter, and the cocoon of a parasite of the borer was found in one of the mines, but the adult parasite was not reared. Many dead borers were found in their mines in the trunks and branches surrounded by a white powdery fungus.

The trees were again examined on September 14, when adults were found abundant on the foliage, branches, and stems, and also on flowers of golden-rod. Adults and pupæ were also found in considerable numbers in the dead wood of broken branches, as well as in the living wood, and dead larvæ were frequent. Larvæ of an elaterid (click beetle) were quite frequent in the wood, where they had evidently been feeding on the locust borer.

Examination during August, 1905, of the locust on a hill near Kanawha Station, W. Va., where this tree forms the principal growth over old abandoned fields and in the adjacent forests, showed that the damage by the borer was very slight in trees of all sizes. On August 26 many adults and a very few pupæ, but no larvæ, were found in small trees in the valley, while the large trees in the same locality were but slightly damaged.

OBSERVATIONS BY MEMBERS OF THE FOREST SERVICE.

The following notes by Mr. S. N. Spring, forest assistant in the Forest Service, were submitted October, 1905, as a contribution to the results of cooperative studies. Early in July the work of the borer was noticed in the central portion of Westmoreland County, Pa. The first adult insect was seen on August 29. Evidence of the work of this insect was found in the localities investigated, but, for the most part, it was not serious enough to prevent the planting of locust for fence posts. To the north and west of Greensburg, in Westmoreland County, and in Allegheny County many roadside trees were badly bored. The work of the borer is slight on Chestnut Ridge and Laurel Hill, where locust thrives. Posts and pit props cut in these mountains show slight injury only. In the few places where injury was found to be great, within the area studied, the trees were dying, and many branches were broken off where the trees had been extensively bored by this insect. Owing to the fact that places of serious injury were so few, it was impossible to carry out any observations that would be of value in a study of immunity. In general the locust on the two high ridges thrived better than those on the lower elevation of Westmoreland and Fayette counties, and less injury due to this insect was found among the trees on the ridges.

Mr. J. W. Fetherolf, of the Forest Service, informed the writer, on January 26, 1905, that a grove of black locust planted in Salt Lake City, Utah, prior to 1850, is still in a thrifty condition and apparently free from all insect injury. The same can be said about this species seen elsewhere in the Salt Lake Valley.

Mr. Wesley Bradfield, of the Forest Service, informed the writer that he found the adult beetles common on badly damaged trees, 5 to 8 years old, near Marshall, Mich., in August, 1905; also, that according to his observation the locust in the southern quarter of Michigan was seriously damaged, while in the northern three-quarters, especially toward Lake Michigan, it was not.

RECENT OBSERVATIONS BY THE WRITER.

On March 11, 1906, it was found at Arlington Farm, Virginia, that the young larvæ had passed the winter in minute cells which they had excavated in the outer layers of the living bark and just beneath the outer corky bark (fig. 5), as recorded by Dearborn. So common were these hibernating larvæ in the trees that in the bark of some of them there were fifteen or twenty within an area of a few square inches;

but of the several hundred examined there was only one larva in a place, which would indicate that the eggs are not deposited in clusters, but that they are scattered about in the crevices, so that each larva occupies a separate hibernating cell. The slight wound thus produced in the outer layer of the living bark results in a small dead area surrounding the cell. This dead and brown condition was found, on the date mentioned, to have penetrated the thick inner bark to the wood. This condition evidently facilitates the operation of the young larva in boring through the inner bark to the wood, which a healthy condition of the immediately surrounding bark might prevent. It is not improbable that this small area of dead bark may be caused by a plant disease, which finds its way to the living plant tissue through the slight wound made by the larvæ and which, if this be so, may contribute greatly to the death of badly infested trees.

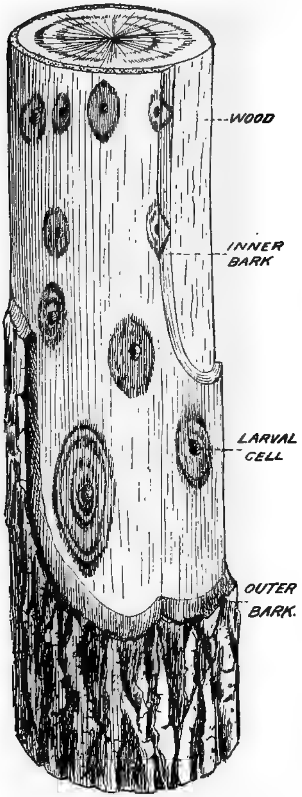

FIG. 5.—The locust borer (*Cyllene robiniæ*): Hibernation or larval cells in outer portion of living inner bark. About natural size (original).

The young larvæ were found in nearly every case in the part of the bark which had not been injured previously, thus indicating that the female deposits her eggs where the bark is perfectly healthy and not in or around the old scars. Indeed, the habit of the larvæ appears to render this quite necessary for their more or less isolated work. It was particularly noted that the remaining unaffected bark of the trees which had suffered most from previous generations of the insect was thickly infested with hibernating larvæ, while that of near-by large trees which had escaped previous injury contained very few, thus indicating that from some cause there are individual trees which are more or less immune. This fact, which has been so often observed, suggests the importance of experiments in the propagation of immune stock by means of seed or root cuttings from immune trees growing among badly infested ones.

The hibernating habits of the larvæ also suggest a simple method of destroying them, namely, the cutting and barking of the trees during the period between the first of November and the first of May. The simple removal of the bark, without burning, is sufficient to kill the larvæ.

It should be remembered that all the holes found in a tree and all other damage by the borer are not the work of one generation, but usually that of repeated annual attack during the life of the tree; also, that a burrow in the sapwood of a young tree remains the same burrow in the heartwood of the old tree, without change, except in the healing of the original entrance; therefore the number of borers and the amount of damage each year is not so great as it might appear, and, while each female is doubtless capable of depositing more than a hundred eggs,[a] it would appear from the writer's observations that only a small percentage of the larvæ hatching from them survive the bark-infesting stage or complete their development to the adult stage. This suggests that any method of management which will insure the destruction of a large number of larvæ and beetles each year will reduce the damage to a point where there will be practically no loss.

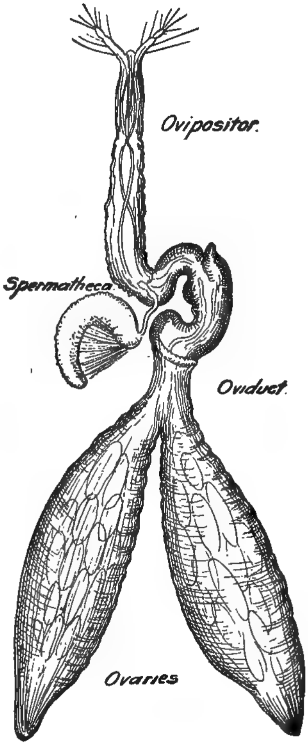

FIG. 6.—The locust borer (*Cyllene robiniæ*): Reproductive organs of female beetle. Highly magnified (original).

SUGGESTIONS FOR CONTROLLING THE INSECT AND PREVENTING LOSSES.

With our present knowledge of the life history and habits of the locust borer, it would appear that the following suggestions might be of practical value in the control of insects in large plantations and forests.

The fact that the young larvæ from eggs deposited during the summer remain in the outer bark during the winter and do not enter the wood until the following May suggests that if locust for all purposes were cut between November and May, the bark removed from that portion which is of value, and the remainder burned, it would destroy vast numbers of the insects and contribute greatly toward the protection of the remaining growth.

The fact that badly infested trees may be detected during May, June, and July by the ejected sap and borings, suggests this simple method of locating such trees, which should be cut close to the ground and burned, before the first of August, to destroy the borers before they transform to the adult beetles and emerge. If preferable, the same end may be accomplished by burning the tops and worthless parts and by submerging the valuable parts in ponds or streams until the borers are killed.

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[a] An examination of the ovaries (fig. 6) of beetles collected in August shows that they may contain as many as fifty mature eggs at one time, in addition to a large number of immature ones.

DAMAGE TO CUT WOOD AND DANGER OF INTRODUCTION INTO NEW LOCALITIES.

As we have shown that after the borers have once entered the wood they may complete their development in the cut and dry branches, they will evidently do so in posts or other material manufactured from trees cut between the first of May and the middle of September; therefore, it is plain that locust should not be cut during this period for any purpose except to destroy the borers, or, if it should be necessary to cut it, the tops should be burned and the logs submerged in ponds or streams for a few days before they are shipped or manufactured. This is very important both to prevent damage to the manufactured material and the introduction of the insect into the far West and other sections of the country which are at present free from it.

PROPER LOCATIONS FOR EXTENSIVE PLANTATIONS.

The fact that there are many sections and localities of greater or less extent within the natural home of the locust and its insect enemies where, from some unknown cause, the tree grows to large size and old age without perceptible injury from borers and other insects, suggests the importance of selecting such localities for any proposed extensive operations in the line of artificial plantation, or utilization of natural growth. It will be found, however, that no area of considerable extent, even in such localities, is entirely free from this and other destructive insect enemies, and that certain precautions and well-planned methods of management with reference to their control will be necessary.

PRELIMINARY REQUISITES.

In the first place it is necessary, in order to provide against future losses from the borer, that a thorough survey be made in May and June, not only of the area to be utilized but of the entire neighborhood for a radius of a mile or more from its borders, for the purpose of locating and destroying scattering trees and groves which are more or less seriously infested or damaged by the borer. It would seem that the control of such large areas, by purchase or under a plan of cooperation between the owners of the land or trees, is one of the most important requisites for success in preventing future losses from the ravages of this and other insects in small as well as large plantations.

In fact, it is the writer's opinion that, with this precaution properly and continuously carried out, locust may be successfully protected from the borer in any locality.

SUBSEQUENT MANAGEMENT.

In the subsequent management of plantations and of natural forest and sprout growth it is important each year to locate and destroy the worst infested trees for the purpose of killing the borers in the wood, and to conduct the thinning and commercial cutting operations during the period between November of one year and May of the next in order to destroy the eggs and young before they enter the wood.

Worthless, scrubby, borer-infested trees should be killed outright by stripping the bark from 4 or 5 feet of the lower stem during August to prevent sprouts and seed production from them and at the same time to destroy the eggs and young borers. Trees deadened in this manner, as was demonstrated near Morgantown, W. Va., some years ago, may be so completely killed that not a single root sprout will appear. Therefore this method is of special value in preventing sprout reproduction from inferior individual trees.

COLLECTING THE BEETLES FROM GOLDEN-ROD FLOWERS.

Collecting the beetles from golden-rod flowers, by means of insect sweep nets, before they deposit their eggs, would be advisable, even for the protection of large plantations, and, as has been suggested, the planting of patches of the plant, or the cutting of all but certain strips and patches of natural growth for this purpose, would serve to concentrate the beetles where they could be caught in the nets and destroyed by emptying them into a pail containing water covered with a film of kerosene.

POISONED BAIT.

Experiments should also be made with poisoned baits, as suggested on pages 7–8.

SUGGESTIONS FOR PROPAGATING BORER-RESISTANT TREES.

FROM SEED (SEXUAL METHOD).

The fact that some trees are, to a greater or less extent, immune from attack or injury by the borer, while adjacent ones in the same grove are attacked year after year and seriously damaged, suggested the idea of breeding races and varieties of the species which would be permanently immune. This suggestion was included in the plan for cooperative investigation mentioned on pages 1–2. It was then thought that if the seed for general planting were collected from immune trees found growing among badly damaged ones, a much larger percentage of the product would resist attack and, by continuing this method of selection and breeding, immune varieties could in time be established. There are, however, some serious difficulties to be overcome by this sexual method, especially that of cross-fertilization and variation and the very long time required to get definite verified results.

FROM ROOT CUTTINGS (ASEXUAL METHOD).

It has since occurred to the writer that insect-resistant varieties might be secured by a much shorter method, namely, that of propagating from root cuttings and possibly from twig cuttings. By this simple method of asexual propagation a large number of offspring, in every respect like the parent stock, may be secured at once for the starting of experiments to determine whether or not the asexual product of trees which have not been injured by the borer will produce plantations equally as immune. The writer's experience in the establishment of improved varieties of timothy by this method leads him to believe that insect-resistant varieties of locust can be established. If so, the principal difficulties in the problem of preventing losses from the ravages of the borer will be solved.

It should be mentioned in this connection, however, that it is possible that the borer, if deprived of the trees which are most attractive to it, may gradually adapt itself to the more resistant ones and become more or less injurious to these, and that other insect enemies may be troublesome. There will be so many advantages, however, in propagating from healthy vigorous stock that, in the writer's opinion, the matter should receive immediate attention, and selection and propagating experiments should be started at once. The success of the effort will depend largely on the proper selection of immune trees from the worst infested groves or sections rather than from those growing in partially immune localities.

Domestic animals and cultivated plants have been improved by selection and breeding to meet almost every need and requirement of man, and it is well known that some races and varieties are much less susceptible to injury by disease and enemies than are others. It is reasonably certain, therefore, that the locust will not be an exception, but that it will yield to the breeders' manipulations and may be made to produce insect-resistant varieties and forms specially fitted to supply the different needs of commercial planting, shade, and ornament.

In the meantime, much of immediate practical value and importance may be accomplished by following the suggestions herein contained for the direct control of the insect in extensive plantations and in natural forest growth.

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SOME INSECTS INJURIOUS TO FORESTS.

THE WESTERN PINE-DESTROYING BARKBEETLE.

(*Dendroctonus brevicomis* Lec.)[a]

By J. L. Webb,
Special Field Agent, Forest Insect Investigations.

INTRODUCTION.

The object of this paper is to give available information on this insect and methods of combating it, with special reference to the results of investigations by the writer during the summer of 1905 in central Idaho.

The need of the investigations was suggested in a letter dated August 10, 1904, from Mr. Gifford Pinchot, forester of the U. S. Department of Agriculture, to Dr. L. O. Howard, chief of the Bureau of Entomology, as follows:

> I learn from the Payette Lumber and Manufacturing Company, one of the Weyerhaeusers, whose land lies on the Payette River north of Boise, that the pine in their holdings is said to be dying from the attacks of insects. If it were possible for you to assign Doctor Hopkins, or one of his assistants, to make examination of this region, unless it has already been done, I should greatly appreciate it, and I should likewise appreciate your sending to Mr. Edgar M. Hoover, general manager of that company at Boise, any information you may have bearing on this subject.

In response to this request the matter was referred by Doctor Howard to Dr. A. D. Hopkins, in charge of forest insect investigations, for attention, and Mr. H. E. Burke, an assistant, was instructed to make preliminary investigations in October of the same year. In May, 1905, the writer was assigned to this work, with instructions from Doctor Hopkins to make a detailed study of the forest insects of the region, with special reference to determining the following points: (1) The relation of the several species of insects to the dying of the trees; (2) the number of species involved, the relation of each to primary and secondary attack, and the life histories of the primary and secondary enemies; (3) the extent of the infested area, the percentage of timber killed each year during the past two or three years within given areas, the approximate losses, etc.; (4) the relation of logging operations to depredations by insects in adjoining forests, and the relation of time of felling timber in regular logging operations to attack by Dendroctonus and other bark and wood boring insects.

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[a] Order Coleoptera, family Scolytidæ.

Accordingly, investigations were begun by the writer on May 17, 1905, with headquarters at Centerville, Idaho, and continued until October 10, 1905.

DEATH OF THE PINE CAUSED BY THE WESTERN PINE-DESTROYING BARKBEETLE.

Observations by the writer served to confirm the conclusion of Mr. Burke that the primary enemy was a barkbeetle identified by Doctor Hopkins as the western pine-destroying barkbeetle (*Dendroctonus brevicomis* Lec.).

CHARACTER OF THE INSECT AND ITS WORK.

The adult insect is a stout, brownish-winged beetle (fig. 7) from one-eighth to three-sixteenths inch in length, which attacks the living trees in swarms, and burrows into the living bark, through the inner layer of which each female excavates winding galleries (fig. 8 and Pls. II, III) in which to deposit eggs. These galleries serve to cut off the natural movement of the sap and completely girdle and kill the tree. In the vicinity of Centerville, Idaho, the eggs, deposited during June, July, or August, in little niches in the sides of the galleries, hatch within 4 or 5 days into small whitish larvæ (fig. 9), which mine at right angles from the primary gallery through the outer layers of the inner bark until they have completed their growth, which requires from about 20 to 30 days. They then bore into the outer corky bark (fig. 12, *a*) where they excavate little cells in which to transform, first to the pupa (fig. 10) and later to the adult. When the broods of the first generation have thus developed—in about 60 or 70 days—they bore out through the bark and fly to other trees to repeat the process and continue their depredations.

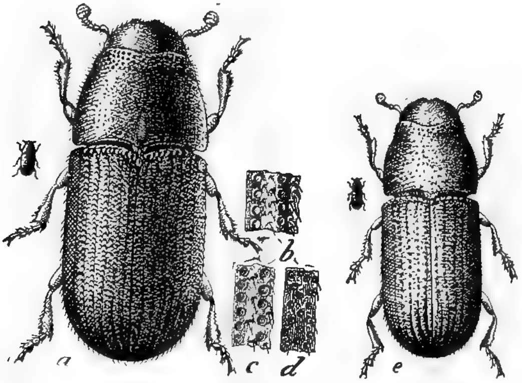
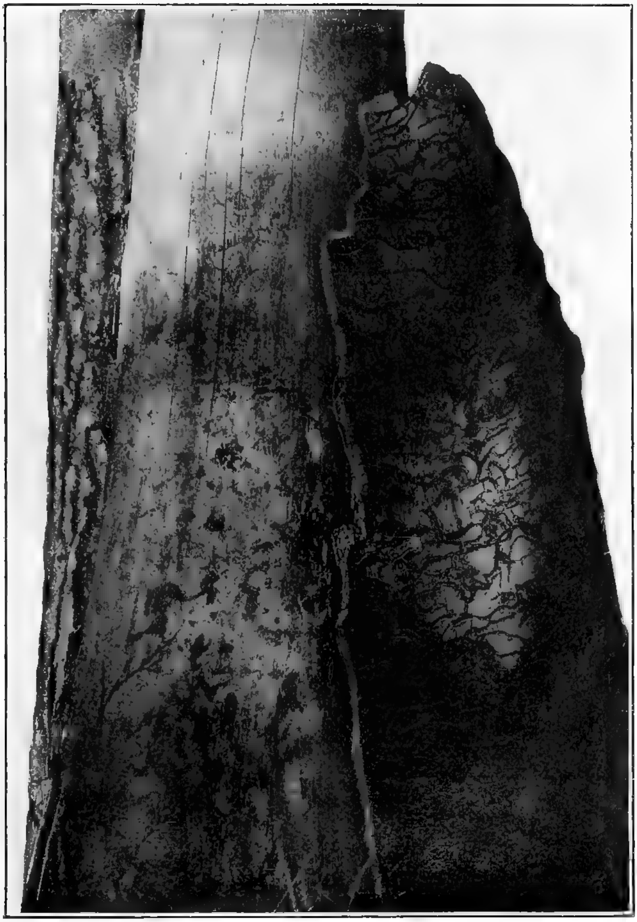
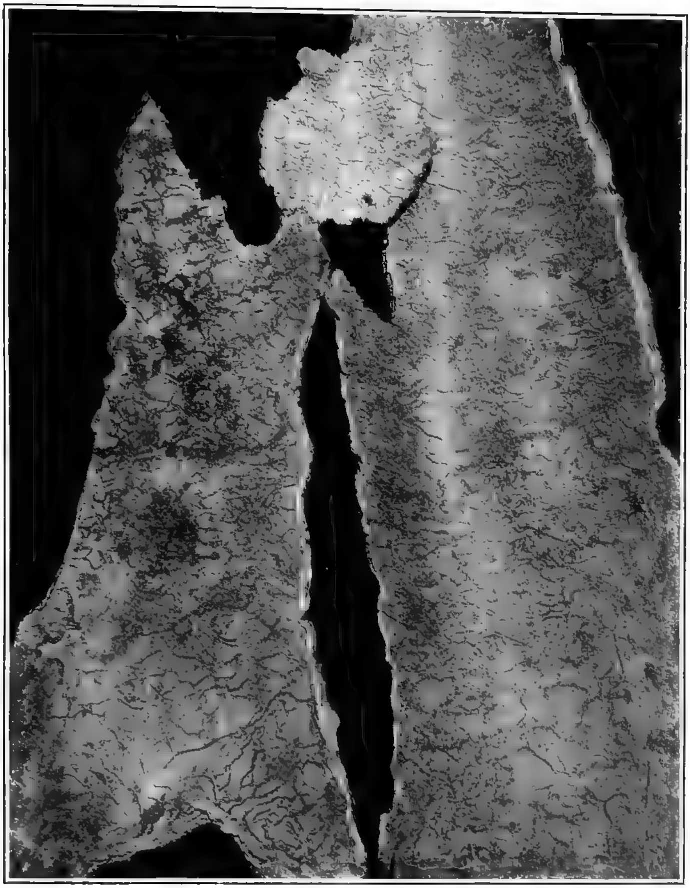


FIG. 7.—The western pine-destroying barkbeetle (*Dendroctonus brevicomis*): *a*, adult female; *b*, *c*, *d*, details of punctuation; *e*, adult male. Natural size at left (original).

The presence of this destructive insect in a forest is indicated (1) by dead and dying trees scattered about or in clumps or large patches. (The dying ones, with fading yellowish and reddish foliage, are called



WORK OF THE WESTERN PINE-DESTROYING BARKBEETLE IN BARK, REMOVED FROM KILLED TREE; ALSO FAINT MARKS ON SURFACE OF WOOD. (ORIGINAL.)



WORK OF THE WESTERN PINE-DESTROYING BARKBEETLE, REMOVED FROM KILLED TREE. (ORIGINAL.)

"sorrel tops," and the dead ones, with reddish-brown foliage, are called "red tops," or, if with bare branches or broken tops, are known as "black tops" or "broken tops;"[a] (2) by small masses of resin (pitch tubes, figs. 11 and 12, *c*) in the crevices of the bark of recently attacked living trees, as well as in those of the dying and dead ones; and (3) the presence of the species is determined by removing the bark from the dying and dead trees and finding the characteristic galleries (fig. 8 and Pls. II, III).

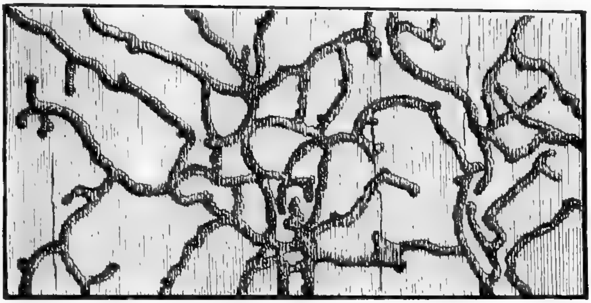


FIG. 8.—The western pine-destroying barkbeetle (*Dendroctonus brevicomis*): Galleries in the inner bark. (Original.)

It must be remembered, however, that there are many different kinds of insects, some of them closely resembling the destructive species, always found in dying pine trees. Therefore, for the general observer to be positive in the matter, specimens of insects and work should be sent to the Bureau of Entomology for authentic identification.

DISTRIBUTION.

The insect is found in southern Idaho throughout, and its range extends to the northern part of the State. It is recorded from California, Oregon, and eastern and western Washington, and, according to Doctor Hopkins, a variety occurs in Arizona and New Mexico and attacks the western yellow pine (*Pinus ponderosa*) and the sugar pine (*Pinus lambertiana*).

EXTENT OF DAMAGE AND LOSSES.

With our present knowledge of the destructive work of this insect, it is evident that a vast amount of timber has been killed by it during the past ten years within the range of its distribution. It is estimated that each year for the past two or three years, from 2 to 5 per cent of the matured standing bull pine timber within the section investigated in the summer of 1905 has died as the result of its ravages.

POSSIBILITIES OF PREVENTING LOSSES.

With our additional knowledge of the life history and habits of the beetle, we are able to suggest practical methods of controlling it and of preventing a large percentage of the losses heretofore caused by its depredations.

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[a] See Bul. 56, Bur. Ent., U. S. Dept. Agric. The Black Hills Beetle.

EARLY HISTORY OF THE SPECIES.

LeConte, in 1876, described the species under the name *Dendroctonus brevicomis* from a single specimen collected in middle California. Dietz, 1890, considered *D. brevicomis* the same as the southeastern species, *D. frontalis* Zimm. Hopkins, 1899, concluded that it was distinct from *D. frontalis*, and therefore that the old name should be retained.

It appears that previous to 1899 nothing had been recorded in regard to the habits and life history of this insect, and that, therefore, the earliest records were made in 1899 by Hopkins, who found it associated with dying sugar pine and western yellow pine at McCloud, Cal., on April 21, 1899, and the next day at Grants Pass, Oregon, with several hundred pine trees which had evidently died from its attack. On May 20, also, at Buckeye (near Spokane), Wash., many trees were found which were dying, or had died, as evidenced by the abundance of the insects and the extent of their work, and on June 6, at Cedar Mountain, Idaho, Doctor Hopkins found it in the bark of pine trees which had been defoliated the previous year by the caterpillars of the pine butterfly (*Neophasia menapia* Feld.). He found also that this beetle was quite intimately associated with the destruction of a large amount of timber only partly defoliated by the caterpillars.

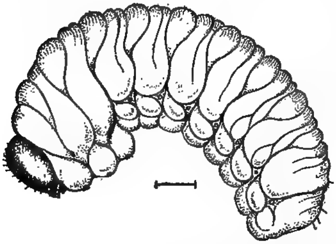

FIG. 9.—The western pine-destroying barkbeetle (*Dendroctonus brevicomis*): Larva. Line below represents natural length (original).

Under his discussion of the principal scolytid enemies of the forests in the Northwest, Doctor Hopkins refers to this species as follows:[a]

> *Dendroctonus brevicomis* Lec. was found to be a most destructive enemy of the yellow pine (*Pinus ponderosa*) in northern California, southern and eastern Oregon, northeastern Washington, and western Idaho. A large amount of some of the finest timber in all of these localities had died within the past seven or eight years, evidently as a direct result of attacks by this bark beetle. It was also found to attack and prevent the recovery of trees injured by defoliating insects and other causes. Its habits and the character of its galleries appear to be identical with those of *Dendroctonus frontalis*, which is noted for its destruction of vast quantities of pine and spruce timber in West Virginia and adjoining States between 1890 and 1893. It is killing the western yellow pine just as *D. frontalis* commenced to kill the eastern yellow pine (*Pinus echinata*) before it spread to all the other pines and spruce. Therefore, just as *D. frontalis* has proven to be the most destructive enemy of eastern conifers, the western representative of this species will doubtless prove to be, under similarly favorable conditions, equally as destructive to the western forests in which the conifers predominate.
>
> Among the most important features observed regarding the habits of this beetle was the fact that it is attracted to trees girdled by settlers and farmers in the process of clearing land, and that in the bark of such trees it breeds and multiplies in sufficient numbers to enable it

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[a] Bul. 21, n. s., Div. Ent., U. S. Dept. Agric., 1899.

to attack and kill the timber in adjoining healthy forests. Indeed, my observation leads me to conclude that a considerable number of girdled pine trees may easily form a nucleus for a destructive invasion by it.

In the same bulletin, under the head of "The western yellow pine," he says:

> It has in *Dendroctonus brevicomis* a most pernicious enemy, which penetrates and excavates winding galleries through the living bark of the finest trees, thus speedily causing their death. Very many trees have died and are dying from this cause, and the dead ones are contributing to the spread of forest fires.

Specimens of the insect and its work occupied a prominent place in the exhaustive exhibit of insect enemies of forests and forest products at the Louisiana Purchase Exposition at St. Louis, in 1904, and the Lewis and Clark Centennial Exposition at Portland, Oregon, in 1905, and were referred to in the catalogues of the exhibits by the Bureau of Entomology.[a]

OBSERVATIONS BY HOPKINS, 1899-1904.

The following summary relating to this species, prepared by Doctor Hopkins from his field notes, includes many facts which have not been published and which have a direct bearing on the life history and habits of the species in different sections of the country where it is found:

McCloud, Cal., April 21, 1899.—Work and dead adults were discovered in a sugar pine log, evidently from a tree which was dying when felled; also dead parent adults in primary galleries, and larvæ and pupæ abundant in outer bark of large dying western yellow pine with the characteristic appearance of eastern pines when dying from the attack of the destructive pine barkbeetle, *D. frontalis.* A few immature adults were found in the outer bark, and evidence that some had emerged. This evidence was in the form of apparent exit holes in the bark, which may have been ventilating holes from main galleries, for with our present knowledge it is not likely that any adults could have emerged so early.

Grants Pass, Oregon, 1899.—On April 24 numerous dying western yellow pine trees were found here scattered through the forest where a severe windstorm had blown down much large timber on September 24, 1895. Young adults, larvæ, and pupæ were found in the outer bark of the standing trees which had evidently been attacked and had commenced to die the previous fall. April 25, numerous trees were observed which died the fall before and others which were not yet dead. One group of 30 young trees about 2 miles north of town were dying at the top, the leaves turning yellow and brown. All trees, without exception, were either infested or had been infested with *D. brevicomis*, and every indication pointed to this species as primarily to blame for the trouble. There were many trees which had been dead for from 3 to 10 years, and in the bark of those dying within the past 4 years traces of the characteristic galleries of *D. brevicomis* were found. No large bodies of timber had died, but the dead and dying trees were scattered all through the forest. A few examples of adults were found mining in living bark of a dying tree, where they had evidently passed the winter, since none of the broods had sufficiently matured to emerge. April 26, eight large trees—five western yellow pine and three sugar pine—which had evidently died in 1897, were observed in the Slate Creek Valley. The western yellow pine exhibited abundant work of *Dendroctonus brevicomis*, and the sugar pine the work of both this and a larger species of the same genus (*D. monticolæ*).

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[a] Buls. 48 and 53, Bur. Ent., U. S. Dept. Agric.

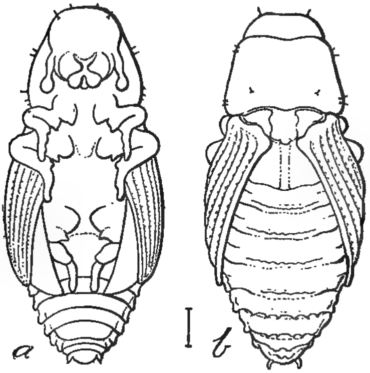

FIG. 10.—The western pine-destroying barkbeetle (*Dendroctonus brevicomis*): *a*, pupa, ventral view; *b*, same, dorsal view. Vertical line in center represents natural length (original).

Buckeye, Wash. (*near Spokane*), *May 22.*—A small western yellow pine tree, evidently killed by the insects, was found. None of the brood had emerged, having died in the bark, possibly from the effects of unfavorable climatic conditions. In another tree killed by this species at this place, young living adults were found.

Cedar Mountain, Idaho (*near Moscow*), *June 4.*—The bark of western yellow pine trees defoliated by pine butterfly larvæ was found to be infested by larvæ and pupæ of *D. brevicomis.* Dead parent adults, also, were found in the primary galleries.

Mariposa County, Cal., June 9, 1904.—Fragments of dead adults were found in primary galleries in bark of a large western yellow pine tree, evidently killed by this species.

Yosemite Valley, California, June 13, 1904.—Western yellow pine trees cut between September 20 and 24, 1903, were found to be thickly infested with larvæ of this species from eggs evidently deposited in September or October.

OBSERVATIONS BY H. E. BURKE, 1904.

From October 20 to 26, 1904, Mr. Burke found the work of this species on western yellow pine quite abundant in the region of Smiths Ferry, Idaho. Under date of October 26 he records observations regarding this barkbeetle in a western yellow pine tree 3 feet in diameter felled some time during that summer; the foliage and bark were living, but red borings on the bark showed where insects had entered. Adults of the Dendroctonus were present in short winding galleries in the living inner bark, two adults to a gallery. Eggs occurred singly in niches on the sides.

He estimated that as a result of the work by this insect near Smiths Ferry 30 per cent of standing timber was dead and 5 per cent was dying. This was at the worst point of infestation, but scattered dying timber was found all over Boise and Payette basins. The same condition extended into the Bitter Root Forest Reserve.

OBSERVATIONS BY THE WRITER, 1905.

The investigations by the writer during the summer of 1905, so far as they related to this species, were mainly for the purpose of determining the principal facts in its life history and habits in the vicinity of Centerville and Smiths Ferry, Idaho. The results may be summarized as follows:

LIFE HISTORY AND HABITS OF THE INSECT.

HIBERNATION.

While it is probable, as observed by Hopkins at Grants Pass, Oregon, that a few parent adults which enter the bark in the fall may pass the winter in that stage, it appears that it is in the young to matured larval stages that the insect normally passes the winter, each individual in a separate mine or cell in the outer corky bark of the tree in which it developed the previous summer and fall. The earliest observations at Centerville were made on May 18, when larvæ, pupæ, and young adults were found. Some of the larvæ were small, but the majority of them were mature and ready to change to pupæ. The pupæ and adults had evidently transformed from larvæ since the beginning of activity in the spring.

The latest date on which larvæ of the hibernating broods were found was June 13. Pupæ were found as late as July 3, and adults July 7. It is therefore evident that the majority of the over-wintering broods develop to the adult stage by about the middle of June, but broods from eggs deposited late in the fall may not develop until nearly the middle of August. Adults begin to emerge in the latter part of May and continue to do so through June and July and into August. Thus the period of activity of the hibernating broods at Centerville is probably from the first warm days in April and May until about the last of July—approximately 90 days—the majority, however, coming out in June and in early July.

FIRST GENERATION.

The first generation at Centerville begins with the first eggs deposited, apparently about the last of June, by the adults developed from hibernating larvæ and pupæ. These eggs hatch in about 4 days after deposition. The principal egg-laying period for this generation is evidently between the latter part of June and the first part of August.

It would appear that the length of time spent in the larval state is from 31 to 35 days. Sometimes, however, a few individuals of this first generation, either from retarded development or other causes, do not go through their transformations with the rest of the broods, but remain as larvæ all through the fall and winter, evidently changing to pupæ in the following spring.

The length of time spent in the pupal stage is approximately 15 days. Pupæ of this generation were observed in different broods from August 14 to September 6.

The first adults, evidently of this generation, were observed in the bark August 14. The length of time spent in the bark after reaching this stage appears to be from 7 to 14 days. It is difficult to tell just when the emergences cease, as the last individuals of the brood come out scatteringly. Thus, on October 10 a few adults were still found in the bark. As this was the last observation, it is not known whether adults emerged later in the fall or whether they passed the winter in the bark before emerging; but the latter was probably the case. In one tree under observation eggs were deposited July 6 and the broods developed and emerged by August 28, a period of 53 days. Thus it appears (1) that the first generation begins with eggs deposited probably in the latter part of June; (2) that the majority of the broods develop and emerge by the first part of September (a period of about 60 days), but that some may continue to develop and emerge until in October; and (3) that possibly some pupæ and young and matured adults may hibernate along with the larvæ. Thus it may require 300 to 390 days or more for the complete development and emergence of some individuals of the first generation.

SECOND GENERATION.

Eggs deposited by adults of what appears to have been the first generation were found August 26 and as late as September 13. It will therefore be seen that there is a partial overlapping of the periods of the two generations.

Larvæ were found as early as September 4, and on October 10, when the last observation was made, some larvæ were apparently full grown.

No pupæ or adults of this generation were found up to the time of the writer's last observations—on October 10, 1905. Mr. Burke found adults, but probably of the first generation, excavating galleries and depositing eggs as late as October 26, 1904. Thus it appears that the second generation, beginning with the first eggs deposited by adults of the first generation, passes the winter in the larval stage and develops and emerges by the middle of the following June to the first part of July. It therefore occupies a period of about 315 to 330 days, including about 60 days of activity in the fall, 165 days of hibernation, and 90 to 105 days of activity in the spring and early summer.

It is probable that at higher elevations and farther north the majority of the broods would not develop in much less than a year's time and that at more southern and warmer localities in the Pacific Coast region there would be two complete generations and possibly a partial third.

HABITS.

When first transformed, in May and June, the young beetles have very soft, delicate tissues. They therefore remain in their pupa cases until their bodies are fully hardened or chitinized. When nearly ready to emerge, the adults bore their way almost to the surface of the bark (fig. 12, *a*), but pause before emerging, appearing to rest in the burrows they have just made. They do not, however, hollow out the space immediately adjoining the pupa case, as is the habit of another species of this genus. When quite ready to emerge, the beetles continue their burrows out through the remaining portion of the bark. The individuals of a brood do not appear to emerge simultaneously, but they come forth at irregular intervals until all are out, leaving the bark thickly punctured with small, round, clean-cut holes, as shown in figure 12.

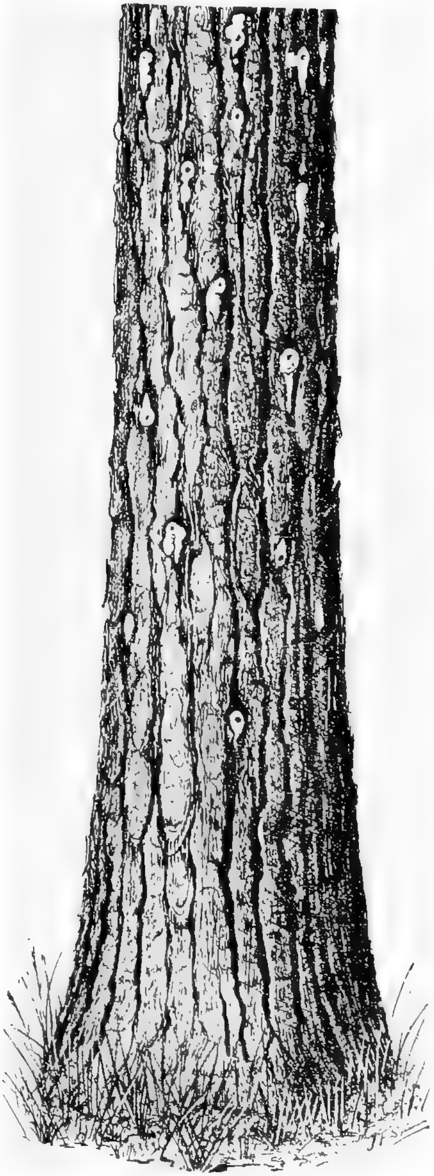

FIG. 11.—The western pine-destroying barkbeetle (*Dendroctonus brevicomis*): Pitch tubes on bark of tree. (Original.)

After leaving the tree or trees in which they went through their transformations the beetles fly away to find trees in which to deposit eggs. They may select trees close at hand or may fly quite a long distance before making a selection. They will also enter the living bark of recently felled trees. Large numbers of the beetles usually settle upon a few trees close together and crawl about upon the bark from near the base to about two-thirds of the distance to the tree's top, seeking suitable places for entrance. Crevices in the bark are favorite places with them for this purpose. The female appears to bore the entrance hole in the bark, and may or may not be closely followed by her mate. In some cases where galleries had just been started, females were found alone, that is, one female to a single gallery. In others, the female was followed by the male. As the first incision is made into the living inner bark, the tree begins exuding pitch to cover the wound made by the intruding beetle. This pitch or resin collects at the mouth of the entrance hole in the form usually known as a pitch tube (figs. 11 and 12, *c*). Where the attacking force of beetles is small, the efforts of the tree to heal these wounds not infrequently succeed, the flow of pitch being so great as to overcome and suffocate the beetles. In such cases the dead beetles may be found in the pitch masses after the tree has recovered. Where the attacking force is large, however, the flow of pitch does not seriously hinder the beetles. After completing the egg laying, the parent adults remain for some time in the galleries and excavate irregular branching burrows toward the end farthest from the entrance, where they remain until they die.

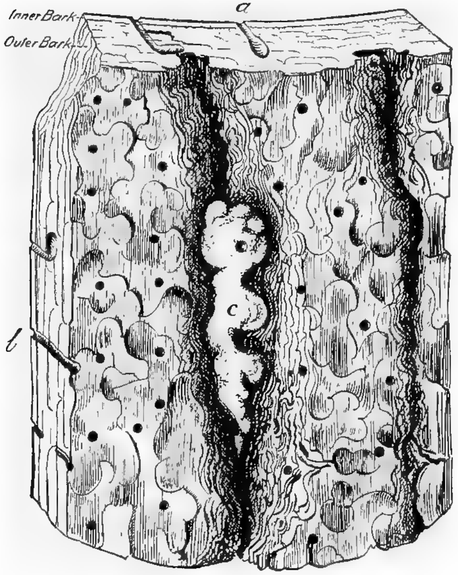

FIG. 12.—The western pine-destroying barkbeetle (*Dendroctonus brevicomis*): *a*, hibernating or transformation cell; *b*, exit burrow; *c*, pitch tubes and exit holes. (Original.)

After successfully effecting their entrance into the bark, the females excavate, through the inner layer of bark, winding, irregular galleries, which run into and cross each other many times (fig. 8). The eggs are laid at the sides of the gallery, each in a little niche hollowed out to receive it and packed in with the borings made in excavating the gallery.

Almost immediately after hatching the larva begins feeding upon the cambium surrounding the niche in which it hatched. For a few days it remains in the cambium, then bores out toward the outer bark. As it progresses, it is at the same time growing, and this growth is indicated by its constantly widening mine or burrow, which is made larger to accommodate the size of the body. Having reached the outer bark, it hollows out an oval space or pupa case, in which to go through its transformations.

NATURAL ENEMIES.

INSECTS.

Larvæ of the predaceous beetles of the genus Clerus, which are known to prey upon Dendroctonus larvæ, were quite common in and under the bark of the infested trees, and they doubtless help to some extent in keeping down the numbers of the barkbeetles.

BIRDS.

Birds contribute their part also in destroying larvæ and pupæ. The work of woodpeckers was found upon most of the trees which had been killed by *D. brevicomis*, and these birds had evidently destroyed a large percentage of the insects in some of the trees.

METHODS OF COMBATING THE INSECT.

FIRST RECOMMENDATIONS.

The following information and recommendations relating to this insect and methods of preventing losses from its ravages were conveyed by Doctor Hopkins to Mr. E. M. Hoover, of Boise, Idaho, manager of the Payette Lumber and Manufacturing Company, in a letter dated January 23, 1906, and afterwards published, with Mr. Hoover's reply, in a local newspaper.

> ...... Our special field agent, Mr. J. L. Webb, has submitted his report on forest insect investigations in the vicinity of Centerville and Smiths Ferry, Idaho, during the past summer, and it will interest you no doubt to know that the insect which is primarily to blame for the death of pine trees was located and thoroughly studied by him.
>
> He found that the broods of the destructive species pass the winter in the grub state in the bark of trees which died during the late summer and fall and that they do not transform to the winged form and emerge until after the 1st of May. Therefore the method of combating the pest is simply to cut the infested trees any time between the 1st of October and the 1st of May and to remove the bark from the main trunk and burn it.
>
> It is necessary to burn the bark in order to kill the broods of this insect, because they occupy the intermediate portion between the inner surface and the outer scale portion; hence the drying of the removed bark will not kill them as it would if they occupied the inner moist portion.
>
> The infested trees can be located (1) by the yellowish and light reddish brown color of the foliage; (2) by cutting into the bark as high up on the trunk as a man can reach with an ax to determine whether the middle portion of the bark is infested with the small white grubs, which are about three-sixteenths of an inch long. If these are found, it will be conclusive evidence that the tree has been killed by the beetle and is infested with its broods. It must be remembered that there are hundreds of other kinds of insects which occupy the *inner* portion of the bark and wood of such trees, but none of the smaller ones pass the winter in the *outer* bark. * * *
>
> Perhaps the most important thing for you to do as a preliminary to any definite action you may take in the matter is to have a number of intelligent cruisers make a survey of your holdings for the purpose of locating the principal sections in which trees have died during the

past summer and the location of the larger clumps and patches of infested trees within such sections; then, if the locations of the infested areas and clumps are indicated on a map, it will aid materially in planning effectual operations. If you could conduct your logging operations in these sections and utilize the infested trees the desired results would be accomplished without much expense. It is not necessary that all scattering infested trees should be felled and barked, but it is of the greatest importance that all of the larger clumps and patches within the worst infested areas should be thus treated within the period mentioned. If this can not be done this year, the work of locating infested areas should be conducted next summer (1906), in order that the more important sections may receive attention next fall and winter.

We shall hold ourselves in readiness to give you further information and suggestions on subjects which may not be clear to you, and whenever there is doubt about the insect or its work specimens should be sent to us for authentic identification.

In response to this letter, Mr. Hoover wrote:

We are most gratified with the information given us and feel that it will be of much value to us in our woods operations. * * *

The ferreting out of the insect pest and advising a way to combat it is a work of great value to the country and of especial interest to all persons interested in forests, and we wish to add our word of appreciation of the service of your Bureau.

Your letter is clear and explicit, and we will be glad to take advantage of your suggestions in our logging operations and have conveyed the information to other lumber companies operating in this vicinity.

Doctor Hopkins has, since then, prepared the following additional recommendations and summary:

TRAP TREES.

With our present knowledge of the life history of the western pine-destroyer and its habits of attacking girdled and felled trees, it is evident that trap trees[a] may prove effective in keeping the insect under control, especially in localities where only a few trees are being killed each year or after a large number of the infested trees have been felled and barked in a badly infested locality.

The time to girdle and fell trees to catch the first generations would be about the middle of June, the bark to be removed and burned in about 20 to 25 days, or before the broods emerge. Girdled or deadened trees are prepared by the "girdle to heartwood" method—that is, cutting through the sapwood all around the trunk 3 or 4 feet above the base or as high above the base as convenient to chop; for this purpose large, inferior trees should be selected.

Felled trees should be lodged or allowed to fall on logs, rocks, etc., so that the prostrate trunks will be as far as possible from the ground. Trees prepared in this manner will usually be attacked by swarms of the beetles, which will excavate galleries in the bark and deposit their eggs. After the eggs have hatched and the larvæ are about full grown, the removal and burning of the bark will effectually destroy the broods and thus contribute greatly to reducing the numbers of the beetles—

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[a] Living trees girdled or felled at the proper time to attract the flying beetles to them and away from healthy trees.

which must occur in large numbers before they can attack and kill a tree. Some of the living trees in the immediate neighborhood of the trap trees may be attacked by beetles attracted to the vicinity by the felled or girdled trees. These should be felled and treated the same as trap trees.

If the conditions appear to warrant it, additional trees should be girdled or felled about the first part of August to catch the second brood. These may be barked, to kill the broods, any time between the first part of October and the first part of the following May.

SUMMARY.

HABITS AND LIFE HISTORY.

The western pine-destroying barkbeetle usually attacks and kills the best examples of western yellow pine and sugar pine.

If neglected and under certain conditions favorable to the species, it is capable of devastating the pine forests over large areas. The broods of the beetle pass the winter in the outer bark of trees killed by it the previous summer. The adults of the overwintering broods emerge and fly in May, June, and July, the beginning and ending of the period varying with the seasons, latitude, and altitude.

The first eggs from the first generation are deposited in June or July, and in some of the warm localities possibly as early as the middle of May. In localities intermediate between the colder and warmer regions the majority of the adults of the first generation evidently develop and emerge in August, but some individuals may remain in the trees until June of the next year.

The first eggs of the second generation are evidently deposited in August and September, depending on locality, and it would appear that in intermediate localities all of the broods of this generation pass the winter (hibernate) in the larval stage in the outer bark. In the warmer localities some of them may develop and emerge in the fall, while in the colder localities there may be but one generation.

The first evidence of attack on living trees is the presence of pitch tubes (figs. 11 and 12, *c*) on the bark or of reddish borings lodged in the crevices and around the base of the tree.

During the fall, winter, and following spring, after a successful attack, the infested trees will be indicated by the fading yellowish and reddish leaves.

The work of the insect will be indicated by the winding galleries through the inner bark (fig. 8). Trees from which the broods have emerged will be indicated by large numbers of small holes through the outer bark (fig. 12).

REMEDIES.

The principal areas of infestation and the principal patches of infested trees should be located in September and October.

Beginning with the first part of October, the infested trees should be felled and the bark removed from the main trunk and burned, these operations to be completed by the first part of the following May.

If all of the trees within a given area can not be thus felled and treated, the work should be concentrated on the larger clumps and patches of infested trees.

The cost per tree for cutting, barking, and burning the bark will range from about 30 cents to $1, depending on locality and accessibility.

Summer cutting, except in regular logging operations, is undesirable, since the cutting of a few trees in the midst of a large forest may attract the insects from a long distance, and thus result in extensive depredations in bodies of timber which it is most desirable to protect.

TRAP TREES.

In sections where it is known that the beetle is killing some of the timber, trap trees should be provided in June and August. Ordinarily, 4 or 5 inferior living trees within each section, on which there is evidence of the work of the beetle, should suffice.

Trap trees should not be prepared unless it is reasonably certain that the bark will be removed and burned before the broods of the beetles develop and emerge, otherwise such trees may contribute to the destruction of a larger amount of timber.

STORM-FELLED OR LIGHTNING-STRUCK TREES.

Storm-felled and lightning-struck trees are a menace to a healthy forest within the distribution of this insect, since they serve as breeding places and centers of infestation. Therefore, whenever practicable, such trees should be watched, and if found infested with broods of this beetle, they should be treated as recommended for infested and trap trees.

PUBLICATIONS RELATING TO THE WESTERN PINE-DESTROYING BARKBEETLE.

1876. LeConte, J. L.—The Rhynchophora of America North of Mexico. Proc. Am. Philos. Soc., Vol. XV, Dec., p. 386. Species described.

1890. Dietz, W. G.—Notes on the species of Dendroctonus of Boreal America. Trans. Am. Ent. Soc., Vol. XVII, p. 32. Revision notes.

1899. Hopkins, A. D.—Preliminary Report on the Insect Enemies of Forests in the Northwest. Bul. No. 21, n. s., Div. Ent., U. S. Dept. Agric., pp. 13–15. First notes on habits.

1904. Hopkins, A. D.—Catalogue of Exhibits of Insect Enemies of Forests and Forest Products at the Louisiana Purchase Exposition, St. Louis, Mo., 1904. Bul. No. 48, Div. Ent., U. S. Dept. Agric., p. 18. Character of work described.

1905. Currie, R. P.—Catalogue of the Exhibit of Economic Entomology at the Lewis and Clark Centennial Exposition, Portland, Oregon, 1905. Bul. No. 53, Bur. Ent., U. S. Dept. Agric., pp. 74 et seq. Reprinted from Bul. 48.

U. S. D. A., B. E. Bul. 58, Part III.
F. I. I., March 5, 1907.

SOME INSECTS INJURIOUS TO FORESTS.

ADDITIONAL DATA ON THE LOCUST BORER.

(*Cyllene robiniæ* Forst.)[a]

By A. D. Hopkins,
In Charge of Forest Insect Investigations.

This part of Bulletin 58 contains a partial revision of Part I, with additional information based on the results of subsequent investigations by the writer and one of his assistants, Mr. W. F. Fiske.

SEASONAL HISTORY.

The data under this head refer to the District of Columbia and vicinity, latitude 39°, altitude 10 to 90 feet above tide.

HIBERNATION.

Hibernation begins soon after the larvæ hatch from eggs deposited at various times from August to October, and the period is passed as minute larvæ, scarcely longer than the eggs from which they hatch, in small individual hibernating cells excavated by them just beneath the corky bark and in the outer layers of the living bark on the main trunk of the larger to small trees or small saplings, and larger to small branches.

ACTIVITY OF THE OVERWINTERED LARVÆ.

Activity of the overwintered larvæ begins in April, or with the beginning of the movement of the sap in the bark and just before the leaf buds open. In 1906 activity began April 11; on April 13 the more advanced individuals had entered to the wood, on the 16th were grooving the surface, and on the 25th some of them had entered the wood. By May 11 nearly all of them had entered the sapwood and some of them had extended their burrows into the heartwood and were rapidly increasing in size and very active, so that by May 20 some of them were more than half grown. They continued actively feeding and growing until after the middle of July, when they began to transform to pupæ and continued transforming during August until all had transformed, probably by the 1st of September. The pupæ begin transforming to adults about the 1st of August and continue transforming probably into September, although the principal transformation is in August.

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[a] Order Coleoptera, Family Cerambycidæ.

ACTIVITY OF THE ADULTS.

The adults begin to emerge as early as the 7th of August, and continue emerging until the last of September, the greater number coming out during the last part of August and the first half of September. Evidently all beetles are out by the first week in October.

The females begin to deposit eggs within a few hours after they emerge. The principal period of oviposition appears to be between the middle of August and middle of September, but oviposition continues until in October. The eggs hatch within eight or ten days after they are deposited, and the young larvæ excavate their hibernating cells and remain dormant until the following spring.

VARIATION IN SEASONAL HISTORY BETWEEN DIFFERENT LATITUDES AND ALTITUDES.

Phenological investigations of plants and insects by the writer[a] during the past ten years indicate that the average difference in the dates of occurrence of the different stages of *Cyllene robiniæ* at different latitudes and altitudes in the eastern United States will not be far from four days later for each degree north of latitude 39° and for each 400 feet of altitude above Washington at the same latitude, or four days earlier for each degree south of latitude 39° at the same altitude.

Thus, at latitude 43° in central New York, or central Michigan, with altitude the same as at Washington, the dates would be about sixteen days later, and at altitudes of 1,000 feet at latitude 43° they would be about twenty-six days later; at the same altitude as that of Washington at latitude 35° in southern North Carolina and Tennessee they would be about sixteen days earlier or at 1,600 feet elevation about the same. Thus we would have about thirty-two days' difference between localities at the same altitude in central New York and southern North Carolina. We would also have thirty-two days' difference between Washington and localities at latitude 39° and altitudes of 3,200 feet in the mountains of Virginia and West Virginia.

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[a] Bull. 50, W. Va. Agric. Exp. Sta., 1898, pp. 17, 18, and Bul. 67, 1900, pp. 241–248, with map.

HABITS OF LARVÆ AND ADULTS.

When a larva begins activity in the spring it molts and proceeds to excavate an independent food and entrance burrow through the dead area of bark surrounding the hibernating cell or through the living bark immediately surrounding the dead area, until it reaches the cambium. It then excavates an irregular groove or cavity in the outer sapwood, returning frequently to the outer cell or opening to push out the borings and apparently to get relief from the exuding sap. A large per cent of the larvæ die before any further progress is made, but survivors grow rapidly and soon succeed in overcoming the many obstacles, including natural enemies, resistance of the tree, etc., and enter the sapwood. From this stage on until the larvæ have attained their full growth they are very active and destructive. Their food consists principally of the nutritious substances of the bark and wood, and probably of the liquids flowing into the burrow, but they do not hesitate to kill and feed upon each other when two or more come in contact within the same burrow. The fact that the entire development often takes place in a burrow scarcely more than twice the length of a matured larva indicates that food must be obtained from some source other than the wood and bark. Throughout its active life the larva frequently returns to the inner and outer bark to enlarge the burrow, and push out its borings, so that the burrow when completed is of a diameter throughout sufficient to allow the passage back and forth of the full-grown larva. When full grown the larva enlarges the inner end of the burrow, plugs the outer portion with boring chips, and in due time transforms in succession to the pupa and adult. When the adult is fully matured it escapes through the exit prepared by the larva. Immediately after a female emerges she is joined by one or more males, and within a few hours, or within twenty-four hours, she proceeds to deposit eggs. She runs about over the bark investigating the crevices, by means of her ovipositor, to locate those most suitable for an egg. Sometimes as many as twenty places are critically examined before one is selected, and it appears that but one egg is deposited in a place by the same female, but other females may find the same place and each deposit an egg, so that sometimes several eggs are found in one crevice. As a rule, however, there is but one. The faculty of the female in locating the most suitable place for an egg by means of the sensitive palpi on the tip of the ovipositor is remarkable.

The beetles feed principally on pollen from the flowers of golden-rod, but are very fond of any sweet liquid, such as sugar sirup placed on the trunks of the trees. They are found during the day on the trunks, branches, and foliage of the locust, and during their principal period of activity, from toward the last of August to the middle of September, they are especially common on the golden-rod flowers. Mr. Fiske determined that they were also actively copulating and depositing eggs as late as 10 o'clock at night.

The attack of this insect is apparently confined to the black or yellow locust (*Robinia pseudacacia*).

ECONOMIC FEATURES.

DESTRUCTIVE CHARACTER OF THE WORK.

The destructive character of the work of the locust borer is a matter of great economic importance. This insect attacks the otherwise perfectly healthy trees, and in addition to causing the detrimental wormhole defects in the wood it often kills the trees or renders an otherwise valuable product worthless except for fuel. It is much more destructive in some localities and sections than in others, and also much more destructive to some trees in the same grove than it is to others. It is more destructive also to young saplings and the branches of medium-sized trees than to the larger trees.

The death of a tree is caused principally by injuries to the inner bark and cambium, resulting from repeated attacks. Injuries to the wood alone do not result in the death of trees except when all of the wood is practically destroyed or sufficiently injured to cause the tree to fall or be broken down by the wind.

The commercial value of the wood product is diminished or destroyed by the wormhole defects, but for certain purposes, as, for instance, fence posts, a limited number of such defects are not detrimental, except so far as they may contribute to decay.

EVIDENCES OF ATTACK.

The first evidence of attack is fine brownish boring dust and wet spots on the bark, first observed in April, when the overwintered larvæ begin to enter the inner bark. As soon as the larvæ begin to groove the surface of the wood and enter the sapwood, their presence, in addition to the wet spots, is indicated by yellowish boring dust mixed with liquids and the gum-like exudations. After all of the larvæ have entered the wood their presence is plainly shown by the quantities of yellowish boring dust lodged in the loose bark on the trunk, in the forks of the tree or branches, and around the base. At this stage, usually about the middle of May, the badly infested trees which will die are plainly indicated by the failure of the leaf buds to open, or by the dwarfed or faded and sickly appearance of the foliage, and toward the last of the month and until the larvæ have completed their work in July, by the breaking down of the branches and small trees.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR DESTRUCTIVE WORK.

Favorable conditions for the destructive work of the borer appear to be found in the presence of isolated trees and groves in the open in localities where golden-rod is present or abundant; also, where less resistant varieties of the tree prevail.

Unfavorable conditions are found in forest growth or large areas of pure stands, or mixed stands where the locust predominates; also, in plantations and groves where resistant varieties prevail, and where there is no golden-rod or other favorite food for the beetles. It is also found that coarse, thick bark is less favorable than the thinner bark on old and young trees and saplings.

NATURAL ENEMIES.

INSECTS.

Several predaceous insect enemies of the larvæ have been observed, but so far no true parasites have been discovered. A large elaterid larva (*Hemirhipus fascicularis* Fab.) appears to be the principal enemy of the borer after the latter has entered the wood. It resembles the borer somewhat, but is easily distinguished by the more flattened and shiny body, long prothoracic legs and two curved spines on the last abdominal segment. This predaceous larva is frequently found in the empty mines of the Cyllene larvæ, therefore it is evidently an enemy of considerable importance.

A slender, cylindrical, whitish, footless dipterous larva of an undetermined species is sometimes found in the mines in the wood, and, according to an observation made by Mr. Pergande, it may attack and kill the borers.

Whitish, flattened larvæ of the nitidulid genus Ips, with prominent branched hooks on the last abdominal segment, are common in the sap at the entrance of the mines and in the burrows made by the young borers in the inner bark and outer wood. They are supposed to be sap feeders, but the writer found they would attack and devour young Cyllene larvæ when confined together in a bottle. Therefore it is possible that they kill a great many of the young borers before these enter the wood, which may account, in part, for the disappearance of such a large number of the young borers while in the bark-boring stage.

It was also demonstrated that if several young Cyllene larvæ of various sizes were placed together in a small vial, the larger ones would kill and eat the smaller ones. It is probable, therefore, that when several larvæ hatch from a cluster of eggs and but one survives—which is usually the case—the larger or stronger one has killed the weaker ones.

DISEASE AND SAP FLOW.

Dead larvæ are frequently found in the mines, covered with white flour-like spores, and sometimes these spores are so common that a perceptible cloud rises from the wood when it is split open. Experiments in placing some of the spores with healthy uninjured larvæ in bottles, as well as with those in the normal position in the wood, resulted in the death of the larvæ and the development of apparently the same disease, while the duplicate larvæ kept under the same conditions, but without contact with the spores, remained normal and healthy. Therefore this is a fungus which will kill the borers and one which is evidently of considerable importance.

The profuse flow of sap together with a gummy substance in the wounds made in the living bark and cambium is evidently detrimental to the normal progress of the young larvæ and apparently many of the latter are thus destroyed.

METHODS OF CONTROL.

It should be remembered that all the holes found in a tree and all other damage by the borer are not the work of one generation, but usually that of repeated annual attack during the life of the tree; also, that a burrow in the sapwood of a young tree remains the same burrow in the heartwood of the old tree, without change, as long as the tree exists, except in the healing of the original entrance. The number of borers and the annual amount of damage is not so great, therefore, as might appear, and, while each female is capable of depositing a hundred eggs, only a small percentage of the larvæ hatching from them survive the bark-infesting stage or complete their development to adults. This suggests that any method of management which will insure the destruction of a large per cent of the surviving larvæ and beetles each year will reduce the damage to a point where there will be practically no loss.

With our knowledge of the life history and habits of the insect it is now possible to make definite recommendations and suggestions for its control. Some of those of immediate practical importance are as follows:

TIME TO CUT LOCUST TO DESTROY THE YOUNG LARVÆ.

The cutting of locust for all purposes, including thinning operations and for private or commercial use, should be done during the period between the 1st of October and the 1st of April, the bark removed from the crude product, such as posts, poles, and the like, and the tops and thinnings burned. The removal of the bark from all desirable portions of the trunks of the trees felled during this period is important and necessary in order to destroy the larvæ before they enter the wood. The work in all cases should be completed before the leaf buds begin to swell on the living trees in the spring.

DESTRUCTION OF INFESTED TREES AND WOOD.

When it is desirable to simply remove and destroy, by burning or otherwise, the badly infested and damaged trees to kill the broods of larvæ, the work should be done in May and June, when all such trees can be easily recognized by the boring dust, fading leaves, broken branches, etc., and must be completed before the beetles begin to emerge. Perhaps the best rule, applicable to all localities, latitudes, and elevations, is to complete the work by the time the flowers have all fallen from the trees, which will vary between different altitudes and latitudes from about the middle of May to the last of June. Another rule would be to complete the work before the earliest varieties of golden-rod begin to show evidences of flowering. This, however, would be the latest that the work should be done, because the beetles begin to emerge by the time the first golden-rod flowers appear.

SPRAYING THE TRUNKS AND BRANCHES TO KILL THE YOUNG LARVÆ.

Experiments have demonstrated that the hibernating larvæ may be killed by spraying the trunks and branches with a strong solution of kerosene emulsion. Therefore, when it is practicable or more desirable to adopt this method for the protection of small plantations, groves, or shade trees, the spraying should be done in the fall or winter, not earlier than November 1, and not later than April 1—in other words, during the dormant period of the tree. The following paragraphs, relative to the preparation of kerosene emulsion, are taken from Farmers' Bulletin No. 127, by C. L. Marlatt:

Kerosene emulsion (soap formula)—

Kerosene	gallons..	2
Whale-oil soap (or 1 quart soft soap)	pound..	½
Water	gallon..	1

The soap, first finely divided, is dissolved in the water by boiling and immediately added, boiling hot, away from the fire, to the kerosene. The whole mixture is then agitated violently while hot by being pumped back upon itself with a force pump and direct-discharge nozzle throwing a strong stream, preferably one-eighth inch in diameter. After from three to five minutes' pumping the emulsion should be perfect, and the mixture will have increased from one-third to one-half in bulk and assumed the consistency of cream. Well made, the emulsion will keep indefinitely, and should be diluted only as wanted for use.

For the treatment of large orchards or in municipal work requiring large quantities of the emulsion, it will be advisable to manufacture it with the aid of a steam or gasoline engine, as has been very successfully and economically done in several instances, all the work of heating, churning, etc., being accomplished by this means.

The use of whale-oil soap, especially if the emulsion is to be kept for any length of time, is strongly recommended, not only because the soap possesses considerable insecticide value itself, but because the emulsion made with it is more permanent, and does not lose its creamy consistency, and is always easily diluted, whereas with most of the other common soaps the mixture becomes cheesy after a few days and needs reheating to mix with water. Soft soap answers very well, and 1 quart of it may be taken in lieu of the hard soaps.

In limestone regions, or where the water is very hard, some of the soap will combine with the lime or magnesia in the water and more or less of the oil will be freed, especially when the emulsion is diluted. Before use, such water should be broken with lye, or rain water employed. * * *

For use on locust trees dilute 1 gallon of emulsion with 2 gallons of soft water.

Pure kerosene and pure petroleum will effectually kill the insects, but may do some damage to the bark of the trees.

Experiments with carbolic emulsion indicate that this preparation is of no value to kill the young larvæ.

POISON BAIT.

Experiments showed that the beetles would feed readily on poisoned bait, such as sugar, sirup, or molasses with some arsenical mixed in, when this was smeared on the trees. Such baits are fatal to the beetles, but the danger of killing honeybees is so great that their use is not recommended in localities where honeybees are kept.

DAMAGE TO CUT WOOD AND DANGER OF INTRODUCING THE INSECT INTO NEW LOCALITIES.

We have determined that after the borers have once entered the wood they may complete their development in the cut and dry branches; they will evidently do so, therefore, in posts or other material manufactured from trees cut between the 1st of May and the middle of September; from this it is plain that locust should not be cut during this period for any purpose except to destroy the borers, or, if it should be necessary to cut it, the tops should be burned and the logs submerged in ponds or streams for a few days before they are shipped or manufactured. This is very important, both to prevent damage to the manufactured material and the introduction of the insect into the far West and other sections of the country which are at present free from it.

SELECTION OF LOCATIONS FOR EXTENSIVE PLANTINGS.

The fact that there are many sections and localities of greater or less extent within the natural home of the locust and its insect enemies where, from some unknown cause, the tree grows to large size and old age without perceptible injury from borers and other insects, suggests the importance of selecting such localities for any proposed extensive operations in the line of artificial planting, or utilization of natural growth. It will be found, however, that no area of considerable extent, even in such localities, is entirely free from this and other destructive insect enemies, and that certain precautions and well-planned methods of management with reference to the control of the latter will be necessary.

MANAGEMENT OF PLANTATIONS TO PREVENT INJURY.

In the first place it is necessary, in order to provide against future losses from the borer, that a thorough survey be made in May and June, not only of the area to be utilized but of the entire neighborhood for a radius of a mile or more from its borders, for the purpose of locating and destroying scattering trees and groves which are more or less seriously infested or damaged by the borer. It would seem that the control of such large areas, by purchase or under a plan of cooperation between the owners of the land or trees, is one of the most important requisites for success in preventing future losses from the ravages of this and other insects in small as well as large plantations. In fact, it is the writer's opinion that, with this precaution properly and continuously carried out, locust may be successfully protected from the borer in any locality.

In the subsequent management of plantations and of natural forest and sprout growth it is important each year to locate and destroy the worst infested trees for the purpose of killing the borers in the wood, and to conduct the thinning and commercial cutting operations during the period between October of one year and April of the next, in order to destroy the young borers before they enter the wood.

Worthless, scrubby, borer-infested trees should be killed outright by stripping the bark from 4 or 5 feet of the lower stem during August to prevent sprouts and seed production from them, and at the same time to destroy the eggs and young borers. Trees deadened in this manner will usually be so completely killed that not a single root sprout will appear. Therefore this method is of special value in preventing sprout reproduction from inferior individual trees.

SELECTING AND BREEDING BORER-RESISTANT TREES.

The fact that some trees are more or less resistant to attack or injury by the borer, while adjacent ones in the same grove are attacked year after year and seriously damaged, suggests breeding races and varieties of the species which would be permanently resistant.

Breeding experiments have been begun in cooperation with the Bureau of Plant Industry and the Forest Service, but it will require several years to get definite results. In the meantime, however, it is important that seed and cuttings for commercial planting should be selected, as far as possible, from trees which show least damage from the borer and are otherwise vigorous and healthy. From a well-established principle in the heredity of plants and animals, this practice of propagating from the best examples must certainly yield better results than would follow a disregard of the character of the trees from which seed or root propagations are made.

For reference to literature, and other information not included in this paper, the reader is referred to Part I of this bulletin, pages 1 to 16.

U. S. D. A., B. E. Bul. 58, Part IV. F. I. I., November 10, 1909.

SOME INSECTS INJURIOUS TO FORESTS.

THE SOUTHERN PINE SAWYER.

(*Monohammus titillator* Fab.)

By J. L. Webb, M. S., *Agent and Expert.*

INTRODUCTION.

Monohammus titillator, or the southern pine sawyer, has been known to systematic entomology for over a century. It is somewhat surprising to note, therefore, that scarcely anything is to be found in literature upon the economic importance of this insect, which may truly be said to be one of the most destructive enemies of the crude product of pine forests, especially in the Southern States. Of late years the increasing number of severe storms, so destructive to pine forests in the Southern States, has provided such excellent breeding places for the sawyer in felled trunks and standing stubs that its work is now known to every lumberman in that section of the country as one of the worst injuries to his industry with which he has to contend. The increasing demand by these lumbermen for exact information in regard to the insect rendered necessary a personal investigation of the seasonal history, habits, and facilities for control. To that end the writer spent the months of July and August, 1908, in southern Mississippi, near the town of Baxterville, for the purpose of studying the insect and its habits and conducting a few experiments to determine the best remedy for combating it. Subsequently trips were made to this region in October, 1908, and March, 1909. Investigations were also made, in the latter part of July, 1908, in a district near Kentwood, La., that had been visited by a cyclone, and in a similar district near De Queen, Ark., in October, 1908. The results of these investigations are given in the following pages.

The writer desires to acknowledge, in this connection, the courtesy and kindness of Mr. E. McLennan, of Hattiesburg, Miss., general agent for a company controlling timber land in that vicinity, in furnishing trees on the company's property to be felled for use in seasonal history experiments.

HISTORY.

In 1775 Fabricius published a short description of the adult from a specimen in the British Museum, calling it *Lamia titillator*, and gave its habitat as "Carolina." He also published short descriptions under the same name in 1781 and 1787. Somewhere between 1788 and 1793, the exact date unknown, Linnæus, in the Systema Naturæ, edited by Gmelin, published a short description under the name *Lamia titillator* Fab. In 1792 Fabricius again published a short description of *titillator*, and also published a description of *Lamia dentator*, with "Carolina" as habitat. The latter name has since been placed in synonymy. Olivier, in 1795, published a short description and figure of the adult under the name *Cerambyx titillator* Fab. He gives it the common name "Capricorne chatouilleux" or the "long-horned tickler," and the habitat as "Carolina." At the same time he published a short description and figure of *Cerambyx carolinensis* (common name, the Carolina longhorn), which has since been made a synonym of *titillator*, and gave the habitat as South Carolina. Somewhere between 1795 and 1811, the exact date not being known, the same author published short descriptions of *Lamia titillator* and *Lamia carolinensis*, giving the habitat of the former as "Carolina," and of the latter as South Carolina. In 1805 Beauvois published a short description and figure under the name *Lamia dentator*. In 1835 Serville described the genus Monohammus, and placed *dentator* and *carolinensis* in it, without mentioning *titillator*. Le Conte, in 1854, published a short description and placed *dentator* and *carolinensis* in synonymy. In this connection he says: "Olivier's *carolinensis* very obviously is the female of his *titillator*. * * * It is common in the Southern States."

In 1862 Harris, in his Insects Injurious to Vegetation, published a short description, with a figure and a note on the habits of adults, but stated that the kind of tree the "grub" inhabited was unknown to him. In 1873 Le Conte published a description of *Monohammus minor*, which has since been made a synonym of *titillator*. At the same time he published a short description of *M. titillator*. Of the genus Monohammus, he says: "The species infests pine trees throughout the whole extent of the United States and contiguous northern regions." In the same year Bowditch, under the name *M. dentator*, published short descriptions of the larva, pupa, and adult, and a short note on seasonal history and habits. He found it infesting *Pinus mitis* (*echinata*) in Massachusetts. In 1885 Horn published a short description under the name *M. titillator* and placed the names *carolinensis*, *dentator*, and *minor* in synonymy. He gave the distribution as from Canada to Washington Territory and south to Florida. In 1899 Hopkins published a short note on the occurrence of this species resting upon pitch and scrub pine trees at Tibbs Run, near Dellslow, W. Va. In the same year Chittenden published a a short account of the destructive habits of the species of the genus Monohammus. J. B. Smith, in his Insects of New Jersey, published the same year, mentions this species as occurring throughout the State on pine in June and July. In 1906 Felt, in his Insects Affecting Park and Woodland Trees, under the name *M. titillator* (common name, tickler), published a very short description, saying further that it was met with in very small numbers [in New York] in 1901 on both white pine and hard pine.

DISTRIBUTION.

The records of the Bureau of Entomology indicate that this species is to be found over the whole eastern half of the United States, from Maine to Texas. As stated in the historical notes, Doctor Horn gave the distribution as from Canada to Washington Territory, and south to Florida, but I have not been able to verify his statement as to the northern and western limits of distribution.

HOST PLANTS.

So far as known, this species attacks only pine trees, not favoring any one species of pine, but apparently attacking all species of pine trees within its range of distribution.

CONDITION OF TREES ATTACKED.

Only felled or injured trees are attacked by this species. So far as known, healthy standing trees are never in any danger whatever from this source.

INJURY TO PINE FORESTS BY STORMS.

In September, 1906, a high wind accompanied by rain, blowing steadily for two or three days, uprooted a vast amount of pine timber in the southern part of Mississippi.

In May, 1907, near Tuscaloosa, Ala., a storm occurred which felled about 800,000 feet of pine timber.

On April 24, 1908, a cyclone of huge proportions passed through Mississippi and Louisiana, tearing down a swath of timber from 1 to 2 miles wide (fig. 13). The cyclone passed through some of the finest pine forests in these States, thus bringing down or breaking off many millions of feet of timber. It is quite probable that the same storm did damage in Arkansas. At any rate, two storms occurred in Arkansas, one in April and one in May, 1908, both of which were very destructive to pine timber. During the fall and winter of 1908 two or three more storms occurred in the same State which doubtless contributed to the destruction of the pine forests.

INJURY TO STORM-FELLED TIMBER BY THE SOUTHERN PINE SAWYER.

Practically all timber felled by the storm of September, 1906, became infested by the sawyer. When the writer reached Baxterville, Miss., July 6, 1908, the broods had all matured and emerged from these trees. In this vicinity, where most of his investigations were carried on, from 75 to 90 per cent of the trees felled by the storm of April 24, 1908, were infested by the sawyer. Adults were at that time actively engaged in laying eggs in the uninfested trunks and stubs. This continued for the balance of the summer, so that it is safe to say that a very small percentage of the pine timber injured by this storm escaped infestation. The damage to each log infested is the work of the larvæ or grubs which mine in and through the sapwood, and even penetrate the heartwood, making large unsightly holes which cause the lumber made from this portion of the log to be thrown into the very lowest grade, known to the lumbermen as "No. 2 common."

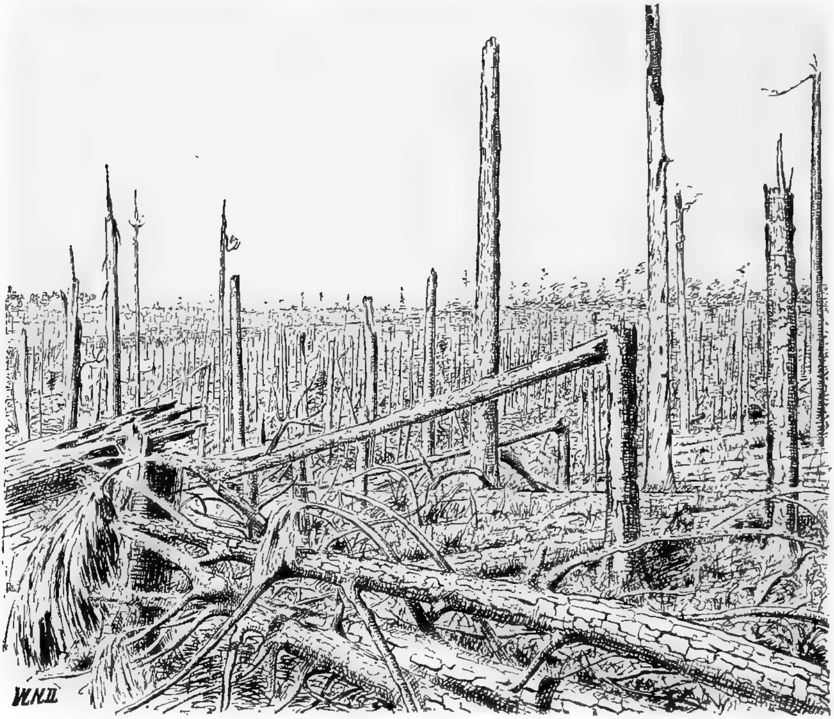

FIG. 13.—The effect of the storm of April 24, 1908. (From a photograph taken near Baxterville, Miss.)

PECUNIARY LOSS.

Approximately 25 per cent of the lumber in each log infested by the sawyer is seriously damaged. The pecuniary loss may therefore be computed as follows: Lumber undamaged by insects was worth, in 1908, $19 a thousand feet b. m. at the mill in southern Mississippi. When infested by the sawyer the 25 per cent damaged was reduced in value to $7.50 a thousand.

It is estimated that in the storm of September, 1908, 2,000,000,000 feet of timber were blown down. In the 1907 storm, in Alabama, 800,000 feet were blown down, and in the storm of April 24, 1908, which passed through two or three States, 180,000,000 feet were blown down. This gives us 2,180,800,000 feet of timber blown down by these three storms. Practically all of this storm-felled timber was damaged by the sawyer.

As stated above, 25 per cent of each log damaged is reduced from $19 a thousand feet to $7.50 a thousand feet; therefore we may consider that 25 per cent of the whole, or 545,200,000 feet b. m. was reduced from $19 a thousand to $7.50 a thousand. At $19 a a thousand this amount of timber would be worth $10,358,800. At $7.50 it would be worth $4,089,000. The difference between these two sums is $6,269,800. Therefore, if this timber had been used, or could have been used before the sapwood decayed, the last figure given would represent the total loss chargeable to the sawyer.

CHARACTER OF THE INSECT.

Adult.—The adult (fig. 14) is an elongate beetle varying from 16^{mm} to 31.5^{mm} in length and from 5 to 10^{mm} in width. The color is a mottled gray and brown. In the male the horns, or antennæ, are very long, often being two or three times the length of the beetle. In the female they are much shorter than in the male, but are still somewhat longer than the body.

Egg.—The egg (fig. 15) is elongate-oval, approximately 4^{mm} long, by 1.5^{mm} in diameter at the middle. The color is opaque white. There are two distinct coverings, which correspond to the outer and inner shells of the egg of a fowl. The outer is known as the chorion (fig. 15, *a*, *d*), and the inner as the amnion (fig. 15, *b*). At one end is found a depression or little round hole, which is known as the micropyle (fig. 15, *c*). Under a high-power microscope the chorion is seen to be very prettily sculptured on its outer surface (fig. 15, *e*).

Larva.—The larva (fig. 16) is an elongate, footless, white grub with powerful jaws or mandibles for boring through the wood. The size varies considerably in different individuals and according to age. The largest at maturity have been found to measure slightly over 60^{mm} in length and 9^{mm} in breadth at the broadest point (the pro-

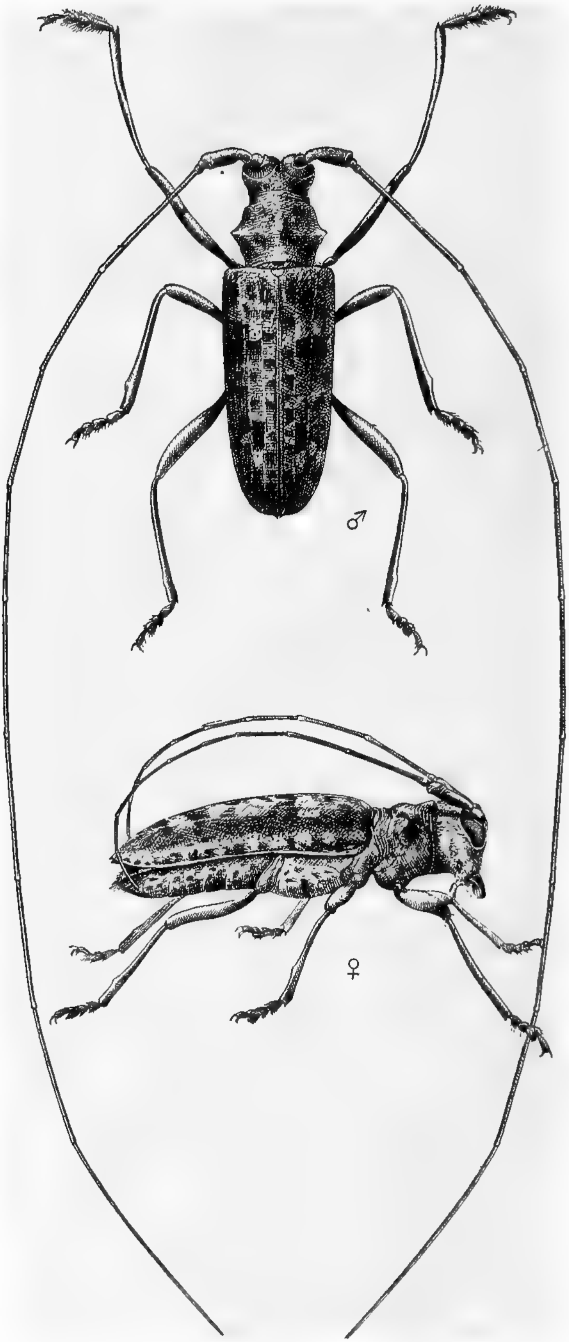

FIG. 14.—The pine sawyer (*Monohammus titillator*): ♂, Male; ♀, female. Enlarged about one-third. (Original.)

thorax). Larvæ which develop into the smaller sized adults are, of course, much smaller than this at maturity. The body is divided into 14 well-marked segments. The first is the head. The following three constitute the thorax, the first being the prothorax, the second the mesothorax, and the third the metathorax. The following 9 segments constitute the abdomen, and are designated as the 1st, 2d, 3d, etc., abdominal segments. The last segment is called the anal segment. The head (fig. 16, *a*) is considerably longer than broad, and is capable of being deeply retracted into the thorax. The prothorax, upon the anterior part of the upper or dorsal surface, is smooth and shining, but the posterior part has an opaque leathery appearance. This opaque surface is dotted over by small shining spots more or less longitudinally elongate in shape. The mesothorax is smooth upon the upper or dorsal surface, but on the lower or ventral surface is found a double transverse row of fine fleshy granules. On the extreme anterior portion of the side of this segment is found a transverse, oval, brown spot. This is the first spiracle or breathing pore. On the metathorax a double transverse row of granules occurs, both on the dorsal and on the ventral surface, but there is no spiracle upon this segment. On the first 7 abdominal segments there are 4 rows of granules on the dorsal surface (fig. 16, *b*), and 2 on the ventral. The

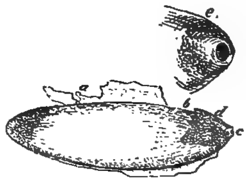

FIG. 15.—The pine sawyer. Egg, greatly enlarged: *a*, Chorion; *b*, amnion; *c*, micropyle; *e*, same, highly magnified; *d*, sculpture of chorion. (Original.)

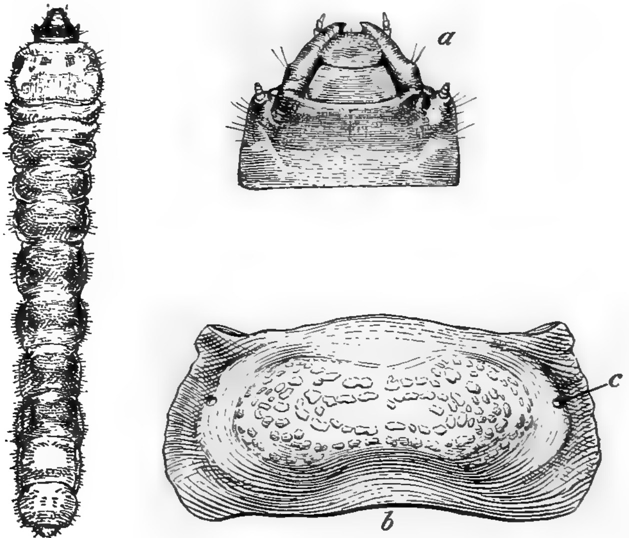

FIG. 16.—The pine sawyer. Larva, slightly enlarged: *a*, Fore part of head; *b*, second abdominal segment; *c*, abdominal spiracle. *a*, *b*, Greatly enlarged. (Original.)

last 2 segments are free from granules. On the anterior half of the side of each abdominal segment except the last, a spiracle (fig. 16, *c*) similar to that on the mesothorax, except that it is much smaller, is to be found. In mature larvæ each abdominal segment bears a longitudinal fold on each side, known as the pleural fold. On immature larvæ the pleural folds on the first 2 abdominal segments are so obscure as to be scarcely noticeable. The anal fold is quite hairy and bears the anal opening. Numerous hairs occur upon each segment of the entire body.

Pupa.—The pupa (fig. 17) shows the form in some degree of both the larva and the adult. The number of segments is the same as in the larva; the first abdominal segment, however, is not visible upon the under side of the body. The head is of the same general shape as that of the adult, but is bent forward and under, so that the mouth-parts point directly back toward the posterior end of the body. Several bristles are found upon the anterior part of the head. The antennæ are well developed and are coiled on the under side of the elytra, or wing covers, which extend from the mesothorax in a posterior lateral direction, the tips being directly underneath the body and attaining the fourth abdominal segment. The elytra thus lie between the body and the first two pairs of legs. The third pair of legs is between the body and the elytra. The wings are flattened against the under side of the elytra, each one projecting slightly beyond the outer side margin of the elytron, under which it lies. The elytra are attached to the mesothorax and the wings to the metathorax.

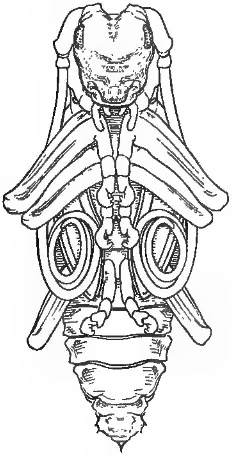
FIG. 17.—The pine sawyer: Pupa. About twice natural size. (Original.)

There is a large fleshy tubercle at each side of the prothorax. The legs are folded underneath the body. The first pair is borne by the prothorax, the second by the mesothorax, and the third by the metathorax. The mesothorax bears a spiracle in the same position as that of the larva, and the first 5 abdominal segments bear spiracles; the rest apparently do not. Upon the dorsal surface all segments of the thorax and abdomen bear bristles. The ventral surface of all abdominal segments, except the last, is smooth. The last abdominal segment, which occupies the extreme posterior end of the body, has a peculiar triangular shape. One of the points of the triangle is prolonged upward into a sharp, chitinized spine. The two lower points of the triangle are armed with several chitinized bristles. The anal segment occurs directly beneath the last abdominal segment, and is inclosed on three sides by the latter. A strongly marked sexual difference is to be found between the anal segment of the male and that of the female. In the male this segment shows merely the anal opening. In the female two globular tubercles are borne side by side on this segment.

SEASONAL HISTORY.

There are four stages in the life of the sawyer, first, the egg (fig. 15); second, the larva (fig. 16); third, the pupa (fig. 17); fourth, the adult (fig. 14).

In southern Mississippi the egg-laying period lasts from about the first of March to the middle of October. In some cases eggs may be laid earlier or later than the dates given, but the main activity in egg-laying will be found to be comprised within this period. The young larvæ hatch from the eggs in about five days after the eggs are deposited.[a]

The length of time from the hatching of the young larva to the time of maturity and change to the pupa appears to vary considerably in different individuals. The comparative periods of time spent in the larval and pupal stages are not known. However, it is probable that while the larval period may last for several months the pupal period is not longer than two or three weeks. The length of time occupied in passing from the egg to the adult stage varies greatly in different individuals. It appears that normally there is one generation a year, with a partial second generation. Thus, on August 12, 1908, the writer found larvæ, pupæ, and emergence holes in the trunk of a tree which had been felled by storm April 24, 1908. The fact that the tree was felled on this date makes it certain that the eggs of the sawyer were deposited subsequently. This gives us a period of less than four months for the development from the egg to the emerged adult, in some individuals. Returning to the same tree October 6, 1908, more emergence holes were found, but there were still plenty of larvæ in the trunk. Also, scattering emergence holes were common at this date in other trees felled by the storm of April 24, 1908, which were also abundantly infested with larvæ. On March 19, 1909, the writer again visited the tree just mentioned, and found a good many larvæ and one pupa still in the log. Thus it is seen what a great variation in the length of time taken for development there may be among different individuals in the same log. The case of the sawyer in the Southern States appears to be somewhat analogous to that of certain species of Lepidoptera, a few adults of which emerge in the fall, while the greater number of the pupæ go through the winter before changing to the adult. In the case of the sawyer, however, the winter is passed in the larval stage and not the pupal stage. In November, 1908, Mr. R. W. Van Horn found emergence holes of the sawyer in trees felled the previous spring near Virginia Beach, Va., thus showing that the same conditions prevail there.

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[a] This statement is based upon observations made during the hottest part of the summer. Possibly eggs laid in the spring or fall might not hatch so quickly, as there would be less heat at those periods.

Among the larvæ which pass the winter in the logs, those which are farthest advanced in development are, of course, the first to go through the changes to the adult, and to emerge in the spring. It is probable that this emergence begins about March 1. At the time the writer was in southern Mississippi, March 18–20, 1909, many adults had already emerged and others were ready to emerge. Females were actively engaged in laying eggs at this time.

Just how long it takes for all the overwintered larvæ, which have not already done so, to go through the changes to the adult stage and emerge is not known, but it is probable that this will be accomplished at least by June 1.

From the last of July, 1908, to the first of February, 1909, the writer had trap trees felled at stated intervals, for the purpose of getting seasonal history notes. The following tabulation shows the net results of these experiments:

Seasonal history records of the pine sawyer from pine trees felled from July, 1908, to February, 1909.

Hopk. U. S. No.	Date of felling.	First eggs noted.	Condition on March 18–19, 1909.
	1908.	1908.	
5873	July 29	Aug. 6	Larvæ and pupæ in wood. A good many adults have emerged.
5874	29	6	Larvæ, pupæ, and young adults in wood. A good many adults have emerged.
5879	Aug. 10	13	Larvæ and pupæ in wood. No emergence holes noted.
5880	10	13	Do.
5885	20	....	Larvæ and pupæ plentiful in wood. No emergence holes noted.
5886	20	....	Larvæ and pupæ common in wood. Three adults have emerged.
5893	31	....	Larvæ and pupæ in wood. Several adults have emerged.
5894	31	....	Larvæ and pupæ in wood very scarce. One young adult (quite small). Two adults have emerged.
5895	Sept. 11	....	Larvæ and pupæ in wood. No emergence holes.
5896	11	....	Larvæ and pupæ rather scarce in wood. A few adults have emerged. A few larvæ between bark and wood, scoring the wood.
5897	28	Oct. 7	Larvæ and pupæ in wood. One larva found between bark and wood, which crawled back into its hole in the wood. One adult has emerged.
5898	28	7	Larvæ, pupæ, and young adults in wood. Several adults have emerged.
5914	Oct. 15	....	Larvæ, some of which have not entered wood, others in wood with exit burrow excavated nearly to surface. No pupæ or emergence holes.
5915	15	....	Larvæ, some between bark and wood, scoring the wood, not having made entrance holes into wood. Others in wood with emergence gallery excavated nearly to surface. No pupæ or emergence holes noted.
5912	Nov. 3	....	A few inconspicuous egg pits evidently made last fall. Two half-grown larvæ, one of which had commenced to mine into the wood. The other had not commenced to do so.
5913	3	....	Two or three egg pits, evidently made last fall, but no larvæ or eggs found.
5910	Dec. 8	....	Many egg pits. Eggs and young larvæ in some cases, in others the conditions seem to have become unfit by reason of the excavations of other insects.
5911	8	....	Many egg pits. Eggs and young larvæ under bark.
	1909.	1909.	
5908	Jan. 7	....	A few egg pits of Monohammus with eggs. One small larva found.
5909	7	....	Scattering egg pits over the log. Eggs and larvæ apparently one or two weeks old.
5906	Feb. 6	Mar. 18	A few egg pits, both in trunk and stump. Eggs under bark, but none found that have hatched. March 20, female digging egg pit.
5907	6	18	A few egg pits with eggs under the bark. One larva found apparently just hatching. March 20, six beetles, three males and three females, observed on this log, the females excavating egg pits, two males fighting and the other male hanging on to a female.

HABITS.

Preparatory to laying the eggs, the female digs with her mandibles quite a conspicuous egg pit in the bark (figs. 18, *a*, and 21, *c*). This pit is more or less funnel shaped, though sometimes it is merely a transverse slit, and reaches as far as the outermost layer of soft, sappy bark. The female, while digging the egg pit, is generally accompanied by the male, who clasps the posterior end of her body with his forelegs, and frequently fertilizes her while she is digging the pit. In one instance where the operation was noted, the female did not discontinue digging while copulation took place. Many combats take place between males for the possession of a female during oviposition. The ovipositor is thrust into the egg pit and in between the soft, sappy bark and the first layer of outer hard bark, and the eggs are deposited in a circle around the bottom of the egg pit, the egg (or the end of the egg nearest the pit) being placed from one-eighth to one-quarter of an inch away from the egg pit (see fig. 18, *b*). As many as nine eggs have been found deposited through a single pit opening.

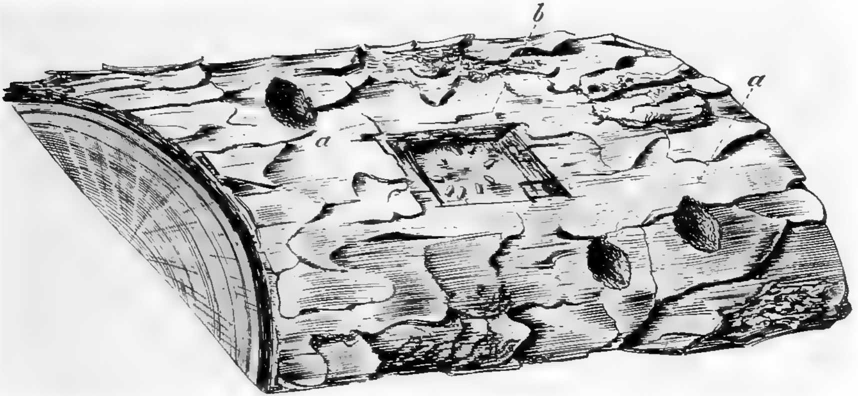

FIG. 18.—The pine sawyer: *a*, Egg pit; *b*, eggs in position in which they were placed by female, the outer bark being removed. About one-half natural size. (Original.)

In about five days these eggs hatch, and the small larvæ issuing therefrom begin feeding upon the soft inner bark, and soon work their way through it, but do not enter the wood until they have attained considerable growth. During this period they make irregular galleries through the inner bark just next to the wood, deriving their entire sustenance from the bark and making no marks or cuttings upon the wood. In from eighteen to thirty-two days after hatching the larvæ mine into the sapwood (fig. 19). A few days previous to this they are to be found cutting rather broad, irregular paths upon the surface of the sapwood with their mandibles (fig. 19, *d*). This process is called "scoring." After making the entrance into the wood the larvæ come out again to feed upon the inner bark, evidently retiring into their holes to rest and for protection from their enemies. The chips cut in excavating the hole in the wood, as well as the excrement, are packed between the bark and wood and are not thrown out upon the ground, as appears to be the case with some other species. In moving about from the entrance of the hole in the wood to the place where food is obtained, very distinct channels are made through this mass of refuse (fig. 21). This habit appears to continue until the larva is ready to pupate, when, of course, it retires to the pupal chamber (fig. 19, *c*) already constructed, where it remains until the adult stage is reached. Previous to pupation the larva extends the gallery in the sapwood until the heartwood is reached. As a general thing the gallery here turns in a longitudinal direction for 2 or 3 inches, then turns again toward the surface, giving the entire gallery a U-shaped appearance (fig. 19). Sometimes the bottom of the "U" extends a short distance into the heartwood, but as a usual thing it merely reaches it. In the bottom of the "U" is to be found the pupal cell. The gallery is here greatly widened and enlarged in order to accommodate the insect while going through its

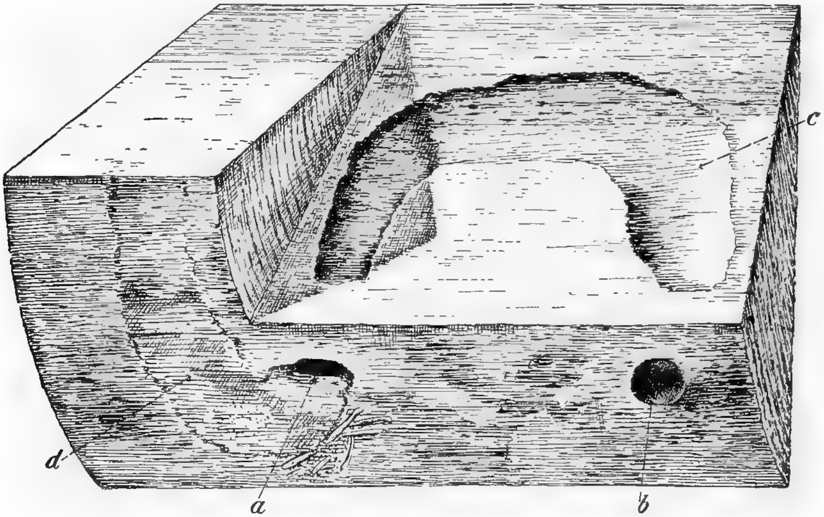

FIG. 19.—The pine sawyer. Gallery: *a*, Entrance hole in wood; *b*, emergence hole; *c*, pupal cell; *d*, surface scored by larva before entering wood. About natural size. (Original.)

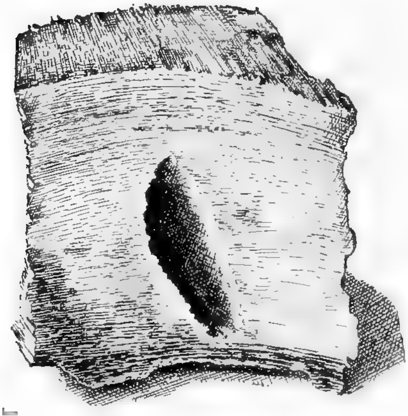

FIG. 20.—The pine sawyer: Cross section of pupal cell. About natural size. (Original.)

transformations (figs. 19, *c*, 20). The unfinished arm of the "U" is usually extended by the larva to within about one-quarter of an inch of the surface of the wood. When the larva pupates, the head of the pupa is turned toward the end of the chamber. When the pupa changes to the adult, the beetle extends the chamber to the surface of the wood and through the bark, if the bark is still upon the tree or log, boring a perfectly round exit hole usually about three-eighths of an inch in diameter (figs. 19, 21, 22), thereby escaping to propagate the species in another tree or trees.

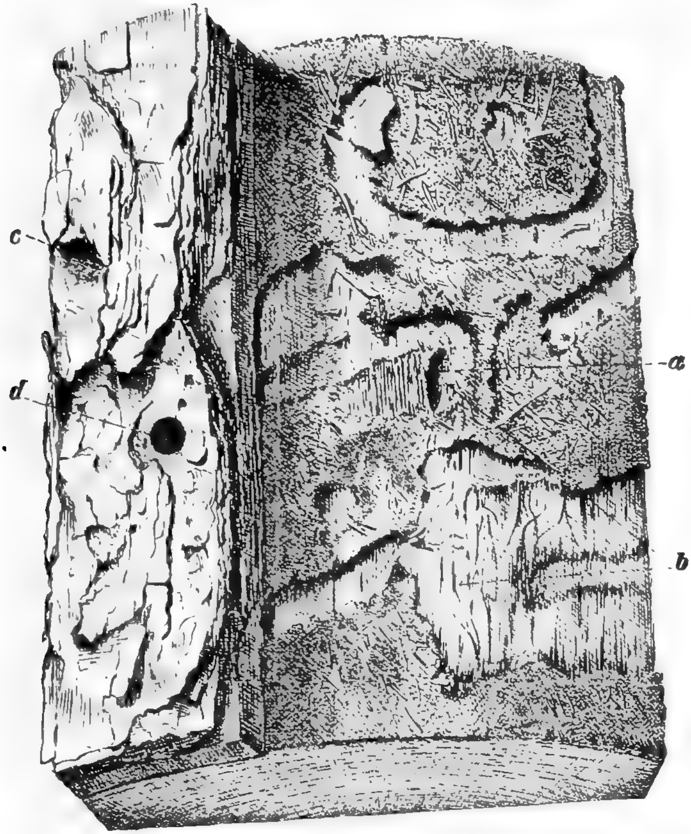

FIG. 21.—The pine sawyer: Section of pine showing, at right, mass of borings and refuse packed under bark (bark removed) by the larvæ and channels made through the mass by the larvæ. *a*, Entrance hole of larva in wood; *b*, scored surface of wood; *c*, egg pit; *d*, emergence hole. About one-half natural size. (Original.)

NATURAL ENEMIES.

Monohammus titillator is preyed upon by larvæ of the coleopterous family Trogositidæ; by the larva of an elaterid beetle of the genus Alaus, and by a species of Bracon which has been determined as new to science. None of these, however, has been powerful enough, so far, to appreciably thin the ranks of Monohammus. Following is the description, by Mr. H. L. Viereck, of the species of Bracon mentioned above:

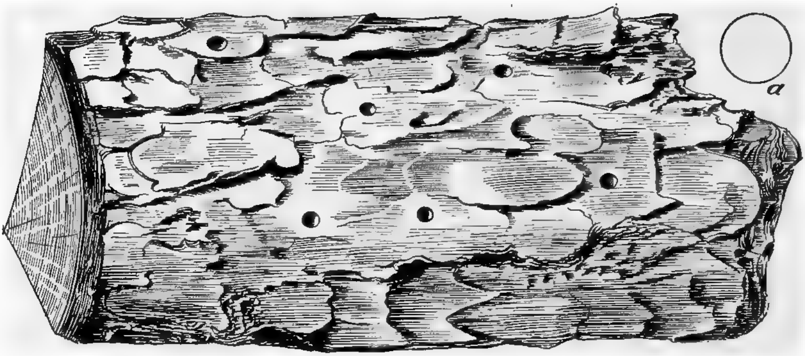

FIG. 22.—The pine sawyer: Emergence holes of young adults in bark. *a*, Natural size of emergence holes. (Original.)

BRACON (MELANOBRACON) WEBBI N. SP.[a]

Compared with *ulmicola* [b] this species differs as follows: Second dorsal abdominal segment without a triangular elevated area but with shallow, almost oblique impressions as diagrammatically represented in figure 23.

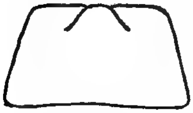

FIG. 23.—*Bracon* (*Melanobracon*) *webbi*: Dorsum of second abdominal segment. Greatly enlarged. (Original.)

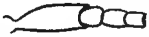

FIG. 24.—*Bracon* (*Melanobracon*) *webbi*: First four antennal joints. Greatly enlarged. (Original.)

Female: Length, 11^{mm}, exclusive of ovipositor, which is 6^{mm}; antennæ 69-jointed; proportions and relation of first four joints approximately as in figure 24; joints 4 to 55 subequal, becoming wider than long; joints 55 to 69 becoming longer than wide, the apical joint conical. Petiole of first discoidal cell about as long as second and third joints of antenna combined. Second dorsal abdominal segment perfectly smooth.

Type.—No. 12585, U. S. National Museum.

Type locality, Baxterville, Miss., March 19, 1909.

Hopk. U. S. No. 5896*a*; reared by Mr. J. L. Webb, of the Bureau of Entomology.

REMEDIES.

Fire.—During the logging operations upon the storm-felled timber near Baxterville, Miss., in 1908, the felled timber was burned over with the object of destroying the broods of the sawyer. Subsequent examinations of this burned-over area disclosed the fact that a very small percentage of the larvæ had succumbed to the heat. *This method is, therefore, not to be recommended.*

Scoring.—Several experiments were tried to determine the efficiency of "scoring," or removing a strip of bark along the upper surface of a log. In some instances salt was sprinkled along the scored surface, and in others the strip was covered with brush, these having been recommended locally as remedies. In not a single instance was the scoring, either with or without salt, found to deter the larvæ in the slightest degree. *This method is not recommended.*

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[a] By H. L. Viereck, Agent and Expert, Bureau of Entomology.

[b] 1906, Trans. Am. Ent. Soc., pp. 176–177.

Placing logs in water.—Investigation of the method of destroying the larvæ in infested logs by placing the logs in water was made at Lumberton, Miss., where logs from the storm-felled trees were placed in the mill pond. The water killed all the larvæ in the log, both between the bark and wood and in the wood itself. *This method is to be recommended wherever practicable.*

Barking the logs.—Barking the logs is effective up to the time the larvæ enter the wood, and for a short time thereafter—perhaps a week. As stated elsewhere, the first part of the life of the larva is spent between the bark and the wood, during which the larva feeds upon the soft inner bark. It is absolutely impossible for the larva to live for the first month of its existence without this soft inner bark to feed upon. Therefore, if the bark be removed from the log during this period all larvæ between the bark and wood will be destroyed. As stated elsewhere, the larvæ continue to feed upon the inner bark for several days at least, after first entering the wood. The writer determined by experiment that the barking of the log during the first few days after the larvæ have entered the wood was effective in destroying the larvæ, by cutting off their food supply. At this period the larvæ have not gone deeply into the wood, so that there would still be a saving if the barking were done at this time. Where this method is practiced as a remedy, it should be done within forty days after the eggs are laid. If trees are felled between March 1 and October 15, egg laying will probably commence at once after the trees are down.

An important point to be taken into consideration in this connection is whether or not logs and trees barked to destroy the sawyer can be taken to the mill before the sapwood decays from lying on the ground. As the greater part of the injury by the sawyer is confined to the sapwood, there will obviously be little or no saving in barking logs which can not be used before the sapwood is destroyed by decay.

The writer realizes, also, that in some cases barking may not be profitable for other reasons. The local conditions in regard to labor are often far from satisfactory. And it may be quite impossible to assemble enough laborers to bark all the trees felled by a heavy storm in time to save them from injury by the sawyer. It is also true that in cyclone-felled timber the trunks are often so piled up and entangled that it would be necessary to saw them into logs and separate them before they could be barked. However, taking all these points into consideration, the writer feels that in the majority of instances a great saving can be accomplished if the matter is promptly taken in hand, and as many trunks as possible barked before or shortly after the larvæ enter the wood. In each case the holder of storm-felled timber must decide for himself. If the cost of barking the felled trunks is low enough to give a fair profit on the material saved from injury, it is a simple proposition of business economy. In any case the matter should be given careful consideration before all effort to prevent loss from the ravages of the sawyer is abandoned.

SUMMARY OF REMEDIES.

If possible saw all storm-felled trunks into logs and place the logs in water before the larvæ enter the wood, or within forty days after the eggs are laid. If it is impossible to place the logs in water, they should be barked within forty days after the first egg pits are observed in the bark.

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U. S. D. A., B. E. Bul. 58, Part V. F. I. I., December 4, 1909.

SOME INSECTS INJURIOUS TO FORESTS.

INSECT DEPREDATIONS IN NORTH AMERICAN FORESTS AND PRACTICAL METHODS OF PREVENTION AND CONTROL.

By A. D. HOPKINS, Ph. D.,
In Charge of Forest Insect Investigations.

INTRODUCTION.

It is the purpose of this part of the bulletin to give a summary of facts, conclusions, and estimates relating to the forest-insect problem as applied to North American conditions and to call attention to its importance in the future management of private, state, and national forests.

The matter is presented in as brief and concise a form as possible, in order that the information may be readily available to the general reader, as well as to the forester and student, and references are made to publications in which more detailed accounts may be found.

The statements and conclusions relating to the insects and their work and to methods for their control are based almost entirely on investigations and observations by the writer and by assistants in the Bureau of Entomology working under his direction, carried on in all of the principal forest areas of the United States. The historical data have been gathered from the publications listed on pages 96–97. The estimates of the amount and value of standing timber killed by insects and of the forest products destroyed and reduced in value through insect injuries to the crude and seasoned products are based on our published results of investigations (pp. 97–100), on unpublished notes, on technical and practical knowledge of the subject, and on the published forest statistics relating to the amount and value of timber, fire losses, etc. (pp. 100–101).

INSECT DEPREDATIONS IN NORTH AMERICAN FORESTS.

CHARACTER AND EXTENT OF DEPREDATIONS.

The records of notable depredations by insects on the timber supply of Europe during the past four hundred years, on that of the

United States during the past century, and especially those that have come under the observation of the writer and assistants engaged in forest insect investigations during the past eighteen years, furnish conclusive evidence that this class of enemies has been, and is now, an important factor in the destruction and waste of forest resources.

INSECTS CAUSE THE DEATH OF TREES.

It has been conclusively demonstrated that certain species of insects are the direct or primary cause of the death of forest trees of all ages, and that from time to time they multiply to such an alarming extent that their depredations assume the character of a destructive invasion, which results in the death of a large percentage of the best timber over thousands of square miles.

There are many species of barkbeetles which prefer to attack matured and healthy trees, and there are many examples of whole forests of century-old trees having perished from the girdling effect of the mines of the beetles, which are extended in all directions through the inner living bark on the main trunks of the trees. Indeed, we find among these bark-boring beetles the most destructive insect enemies of North American forests. Some notable examples of the depredations of these barkbeetles are given below.

The southern pine beetle.—In 1890–1892 a destructive invasion of the southern pine beetle (*Dendroctonus frontalis* Zimm.) extended from the western border of West Virginia through Maryland and Virginia into the District of Columbia, northward into southern Pennsylvania, and southward into North Carolina. In this area, aggregating over 75,000 square miles, a very large percentage of the mature and small trees of the various species of pine and spruce was killed by this beetle. In many places in West Virginia and Virginia nearly all the pine trees of all sizes on thousands of acres were killed, while shade and ornamental trees within the same area suffered the same as those in the forest. Since 1902 this barkbeetle has been more or less active in the Southern States from Virginia to Texas, and in some localities and during certain years it has killed a large amount of timber. Records of extensive destruction of timber in the Southern States are found dating back to the early part of the nineteenth century (Wilson, 1831). This species may be considered one of the most dangerous insect enemies of southeastern conifers and, therefore, a constant menace to the pine forests of the Southern States. (Hopkins, 1899*b*, 1903*b*, 1909*b*.)

The eastern spruce beetle.—During the period between 1818 and 1900 there were several outbreaks of the eastern spruce beetle (*Dendroctonus piceaperda* Hopk.) in the spruce forests of New York, New England, and southeastern Canada (Peck, 1876, 1878; Hough, 1882; Packard, 1890; Pinchot, 1899, p. 74; Hopkins, 1901*a*, 1909*b*).

This species caused the death of a very large percentage of the mature spruce over an area of thousands of square miles. In the aggregate many billions of feet of the best timber were destroyed. The larger areas of this dead timber furnished fuel for devastating forest fires, with the result that in most cases there was a total loss.

The Engelmann spruce beetle.—Another barkbeetle (*Dendroctonus engelmanni* Hopk.), similar in habits to *piceaperda*, has from time to time during the past fifty years caused widespread devastations in the Rocky Mountains region to forests of Engelmann spruce, in some sections killing from 75 to 90 per cent of the timber of merchantable size. (Hopkins, 1908*a*, p. 161; 1909*b*, pp. 126–132.)

The Black Hills beetle.—One of the most striking examples of the destructive powers of an insect enemy of forest trees is found in the Black Hills National Forest of South Dakota, where during the past ten years a large percentage of the merchantable timber of the entire forest has been killed by the Black Hills beetle (*Dendroctonus ponderosæ* Hopk.). It is estimated that more than a billion feet of timber have been destroyed in this forest as the direct result of the work of this beetle. This destructive enemy of the western pine is distributed throughout the forests of the middle and southern Rocky Mountains region, where, within recent years, it has been found that in areas of greater or less extent from 10 to 80 per cent of the trees have been killed by it. (Hopkins, 1902*a*, 1903*b*, 1905*b*, 1908*a*, and 1909*b*, pp. 90–101.)

The mountain pine beetle and the western pine beetle.—The sugar pine, silver pine, western yellow pine, and lodgepole pine of the region north of Colorado and Utah, westward to the Cascades, and southward through the Sierra Nevadas are attacked by the mountain pine beetle (*Dendroctonus monticolæ* Hopk.) and the western pine beetle (*Dendroctonus brevicomis* Lec.), and, as a direct consequence, billions of feet of the timber have died. In one locality in northeastern Oregon it is estimated that 90 to 95 per cent of the timber in a dense stand of lodgepole pine covering an area of 100,000 acres has been killed within the past three years by the mountain pine beetle. Throughout the sugar-pine districts of Oregon and California, as the result of attacks by this same destructive barkbeetle, a considerable percentage of the largest and best trees is dead. (Webb, 1906; Hopkins, 1908*a*, 1909*b*, pp. 80–90.)

The Douglas fir beetle.—The Douglas fir throughout the region of the Rocky Mountains from southern New Mexico to British Columbia has suffered severely from the ravages of the Douglas fir beetle (*Dendroctonus pseudotsugæ* Hopk.), with the result that a large percentage of dead timber is found, much of which will be a total loss. (Hopkins, 1909*b*, pp. 106–114.)

Three other species of beetles, having destructive habits similar to those above mentioned, depredate on the pines of New Mexico and Arizona, and still another has contributed greatly to the destruction of the larch throughout the northeastern United States and southeastern Canada. (Hopkins, 1909*b*, pp. 49, 53, and 77.)

The hickory barkbeetle.—Within the past ten years the hickory barkbeetle (*Scolytus quadrispinosus* Say) has caused the destruction of an enormous amount of hickory timber throughout the northern tier of States from Wisconsin to Vermont and southward through the eastern Atlantic States and into the Southern States as far as central Georgia. (Hopkins, 1904*b*, pp. 314–317.)

The larch worm.—There are also many examples of widespread depredations chargeable to insects which defoliate the trees, thus contributing to their death. Notable among these are the depredations by the larch worm (*Nematus erichsonii* Hartig), which, during several extensive outbreaks since 1880, has killed from 50 to 100 per cent of the mature larch over vast areas in the northeastern United States and southeastern Canada. It is evident that the amount of merchantable-sized timber that has died as the result of defoliation by this insect will aggregate many billions of feet. (Packard, 1890, pp. 879–890; Pinchot, 1899; Hopkins, 1908*a*.)

INSECT INJURIES TO THE WOOD OF LIVING TREES.

It has been determined that insects of a certain class attack the wood and bark of living timber and that, while they do not contribute materially to the death of the trees or give much external evidence of their presence, they produce wounds in the bark and wormhole and pinhole defects in the wood which result in a depreciation in commercial value amounting to from 5 to 50 per cent. These defects in the wood are not detected until after the trees have been felled and the logs transported to the mill and converted into lumber. Thus to the actual damage to the lumber is added the expense of logging and manufacture of the defective, low-grade material, much of which must be discarded as worthless culls. (Hopkins, 1894*a*, 1894*b*, 1904*b*, 1905*a*, 1906*b*.)

The oak timber worm.—One of the most destructive of the class of depredators just mentioned is the oak timber worm (*Eupsalis minuta* Dru.). It enters the wood of the trunks of living trees through wounds in the bark and at the base of broken or dead branches and extends its "pinhole" burrows in all directions through the solid heartwood. The losses occasioned by this insect in the hardwood forests of the eastern United States are enormous and usually affect the wood of the finest examples of old trees. (Hopkins, 1894*a*, 1904*b*.)

The chestnut timber worm.—The chestnut throughout its range is damaged in a like manner by the chestnut timber worm (*Lymexylon sericeum* Harr.). Practically every tree of merchantable size is more or less affected, and a large percentage is so seriously damaged that the product is reduced to that of the lowest grade. It is estimated that the reduction in value of the average lumber product at any given time is not far from 30 per cent, thus involving extensive waste and an increased drain on the forest to supply the requirements for clear lumber. This insect also attacks the oaks, and especially the red oak, the older trees of which are often as seriously damaged as are the chestnut. (Hopkins, 1894*a*, 1904*b*.)

Carpenter worms.—The oaks, especially the white oak and the red oak, are seriously damaged by carpenter worms of the genus Prionoxystus. The holes made by these insects through the heartwood of the best part of the trunks are sometimes 1.5 inches in diameter one way by 0.75 inch the other, thus causing serious damage to the wood. These, with other large wood-boring beetle larvæ, sometimes infest the top part of the trunk and the larger branches of oak trees, where their continued work results first in the dead and so-called "staghorn" top and subsequently in broken, decayed, and worthless trunks. (Hopkins, 1894*a*, 1904*b*.)

Ambrosia beetles.—One of the commonest defects in white oak, rock oak, beech, whitewood or yellow poplar, elm, etc., is that known to the lumber trade as "grease spots," "patch worm," and "black holes." This defect is caused by one of the timber beetles or ambrosia beetles, *Corthylus columbianus* Hopk., which makes successive attacks in the living healthy sapwood from the time the trees are 20 or 30 years old until they reach the maximum age. Thus the black-hole and stained-wood defect is scattered all through the wood of the best part of the trunks of the trees. The average reduction in value of otherwise best-grade lumber amounts, in many localities, to from 25 to 75 per cent. The defect is commonly found in oak and elm furniture and in interior hardwood finish in dwellings and other buildings. (Hopkins, 1893*g*, 1894*b*, 1904*b*.)

The locust borer.—The locust, as is well known, suffers to such an extent from the ravages of the locust borer (*Cyllene robiniæ* Forst.) that in many localities the trees are rendered worthless for commercial purposes or they are reduced in value below the point of profitable growth as a forest tree, otherwise this would be one of the most profitable trees in the natural forest or artificial plantation and would contribute greatly to an increased timber supply. (Hopkins, 1906*b*, 1907*a*, 1907*c*.)

Turpentine beetles and turpentine borers.—While the softwood trees, or conifers, suffer far less than the hardwoods from the class of enemies which cause defects in the living timber there are a few notable examples of serious damage. There is a common trouble affecting the various species of pine throughout the country known as basal wounds or basal fire wounds. It has been found that a large percentage of this injury to the pine in the States north and west of the Gulf States and in the Middle and South Atlantic States is caused by the red turpentine beetle (*Dendroctonus valens* Lec.) and in the Southern States by the black turpentine beetle (*Dendroctonus terebrans* Oliv.). These beetles attack the healthy living bark at and toward the base of the trunks of medium to large trees and kill areas varying in size from 1 to 10 square feet. These dead areas are subsequently burned off by surface fires and are then generally referred to as fire-wounds. The further damage to the exposed wood by successive fires, decay, and insects often results in a total loss of the best portion of the tree, or a reduction in value of the lower section of the trunk of from 10 to 50 per cent. (Hopkins, 1904*a*, 1909*b*.) These and similar wounds in the bark of trees, including those caused by lightning and by the uncovering and exposure of the wood in turpentining, offer favorable conditions for the attack of the turpentine borer (*Buprestis apricans* Hbst.), the work of which, together with that of two or three others with similar habits, is very extensive, and causes losses amounting to from 10 to 50 per cent of the value of the wood of the best part of the trees thus affected. (Hopkins 1904*a*.)

The white pine weevil.—The abnormal development of white pine trees as the result of succesive attacks on the terminals of the saplings and young trees by the white pine weevil (*Pissodes strobi* Peck) is an element of loss of considerable importance, especially in mixed stands and in open pure stands of this timber. The value of such trees is reduced from 20 to 50 per cent below those of normal development, and there is an additional loss from the effect of their spreading branches or crowns in the suppression or crowding out of trees which would otherwise occupy the space thus usurped. (Hopkins, 1906*c*, 1907*d*.)

There are many other examples of insects which damage the wood and bark of living trees, but those mentioned should be sufficient to demonstrate the importance of insects in this relation.

Insect Injuries to the Wood of Dying and Dead Trees.

Timber dying from insect attack and other causes, including fire, disease, storms, etc., is attacked by certain wood-boring insects which extend their burrows through the sound sapwood and heartwood, and thus contribute to the rapid deterioration and decay of a commodity which otherwise would be available commercially during periods of from one to twenty years or more after the death of the trees, depending on the species of trees and on the character of the product desired. This loss often amounts to from 25 to 100 per cent during the period in which the dead timber would otherwise be almost as valuable as if living. (Hopkins, 1894*a*, 1901*d*, 1904*a*, 1905*a*; Webb, 1909.)

CONIFEROUS TREES.

Sawyers.—One of the most striking examples of the destruction or deterioration of the wood of dying and dead timber, familiar to all lumbermen, is the injury to fire-killed and storm-felled pine, fir, spruce, etc., caused by boring larvæ known as "sawyers." These borers hatch from eggs deposited by the adult beetles in the bark of the dying trees, and after feeding on the inner bark for a time they enter the solid wood and extend their large burrows deep into the heartwood. Fire-killed white pine is especially liable to this injury, and is often so seriously damaged within three or four months during the warm season as to reduce the value of the timber 30 to 50 per cent. The shortleaf, loblolly, and longleaf pines of the Southern States are damaged to a somewhat less extent, but instances are known in which more than one billion feet of storm-felled timber within limited areas were reduced in value 25 to 35 per cent within three months after the storm. (Webb, 1909.) The fire-killed and insect-killed sugar pine, silver pine, and yellow pine of the western forests are also damaged in a similar manner and the value of the product greatly reduced within a few months after the trees die. The aggregate losses from this secondary source in the coniferous forests of the entire country contribute largely to the annual waste of millions of dollars' worth of forest products which otherwise might be utilized. (Hopkins, 1905*a*, p. 385; Webb, 1909.)

Ambrosia beetles.—Wood-boring insects of another class, known as timber beetles or ambrosia beetles, cause pinhole defects, principally in the sapwood, although some of them extend their burrows into the heartwood. These insects make their attack in the early stage of the declining or dying of the tree, or before the sapwood has materially changed from the normal healthy condition, and often in such numbers as to perforate every square inch of wood. Thus the wood is not only rendered defective on account of the presence of pinholes, but the holes give entrance to a wood-staining fungus which causes a rapid discoloration and produces still further deterioration of the product.

The sapwood of trees dying from the attack of other insects or from fire, storm, or other causes is often reduced in value 50 per cent or more, and in some cases the value of the heartwood is reduced in a like manner from 5 to 10 per cent. (Hopkins, 1894*a*, 1895*c*, 1898*b*, 1904*a*, 1905*a*.)

Pinhole borers in cypress.—An example of the destructive work of insects which attack dying and dead trees is found in the cypress in the Gulf States, where these trees are deadened by the lumbermen and left standing several months, or until the timber is sufficiently dry to be floated. Upon investigation it was found that trees deadened at certain seasons of the year were attacked by the ambrosia beetles or pinhole borers, and that in some cases millions of feet of timber had been reduced 10 to 25 per cent or more in value. (Hopkins, 1907*b*.)

HARDWOOD TREES.

Roundheaded borers, timber worms, and ambrosia beetles.—The principal damage to dying and dead hardwood trees is caused by certain roundheaded wood-borers (Cerambycidæ) with habits similar to the sawyer, by the timber worms mentioned as damaging living timber, and by ambrosia beetles having habits similar to those that attack the sapwood and heartwood of conifers. All of the hardwoods suffer more or less, but the greatest damage is done to the wood of hickory, ash, oak, and chestnut, which are often reduced in value 10 to 25 per cent or more within the period in which it would otherwise remain sound and available for commercial purposes. (Hopkins, 1894*a*, 1904*a*, 1905*a*.)

INSECT INJURIES TO FOREST PRODUCTS.

Damage is caused by various species of insects which are attracted by the varying conditions prevailing at different stages during the process of utilizing the forest resources, from the time the trees are felled until the logs are converted into the crude and finished product and until the latter reaches the final consumer, or even after it is placed in the finished article or structure. As a result, additional drains are made on the timber to meet the demand for the higher grades of lumber and for other supplies to replace those injured or destroyed. From the writer's personal investigations of this subject in different sections of the country it is evident that the damage to forest products of various kinds from this cause is far more extensive than is generally recognized. This loss differs from that resulting from insect damage to standing timber in that it represents more directly a loss of money invested in material and labor. (Hopkins, 1894*a*, 1903*c*, 1904*a*, 1905*a*.)

CRUDE PRODUCTS.

Roundheaded borers, timber worms, and ambrosia beetles.—Round timber with the bark on, such as poles, posts, mine props, sawlogs, etc., is subject to serious damage by the same class of insects as those mentioned under injury to the wood of dying and dead trees. The damage is especially severe when material is handled in such a manner as to offer favorable conditions for attack (Hopkins, 1905*a*), as when the logs are left in the woods on skidways or in mill yards for a month or more after they have been cut from the living trees. Under such conditions there is often a reduction in value of from 5 to 30 per cent or more, due to wormhole and pinhole defects caused by roundheaded and flatheaded wood-borers and timber beetles. Frequently the insects continue the work in the unseasoned and even dry lumber cut from logs which had been previously infested. They also continue to work in mine props after they have been placed in the mine, and in logs and other material used for the construction of cabins, rustic houses, etc., and in round timbers generally.

The products from saplings, such as hickory hoop-poles and like material, are often seriously injured or rendered worthless by roundheaded and flatheaded borers and wood-boring beetles, sometimes resulting in a loss of from 50 to 100 per cent of the merchantable product. (Hopkins, 1905*a*.)

Stave and shingle bolts left in moist, shady places in the woods or in close piles during the summer months are often attacked by ambrosia beetles and timber beetles. The value of the product is often reduced, as a consequence, from 10 to 50 per cent or more. (Hopkins, 1894*a*, 1905*a*.)

Handle and wagon stock in the rough is especially liable to injury by ambrosia beetles and roundheaded borers. Hickory and ash bolts from which the bark is not removed are almost certain to be greatly damaged if the logs and bolts cut from living trees during the winter and spring are held over for a few weeks after the middle of March or first of April. (Hopkins, 1905*a*.)

Pulpwood, and cordwood for fuel and other purposes, cut during the winter and spring and left in the woods for a few weeks or months or in close piles after the beginning of the warm weather, are sometimes riddled with wormholes or converted into sawdust borings, causing a loss of from 10 to 100 per cent. One example reported from near Munising, Mich., represents a loss of $5,000 from injury to spruce and fir pulpwood cut in the winter and kept in piles over summer.

MANUFACTURED UNSEASONED PRODUCTS.

Ambrosia beetles and other wood borers.—Freshly sawed hardwood placed in close piles during warm, damp weather during the period from June to September is often seriously injured by ambrosia beetles. Heavy 2-inch to 3-inch stuff is also liable to attack by the same insects, even in loose piles. An example of this was found in some thousands of feet of mahogany lumber of the highest grade, which had been sawed from imported round logs and piled with lumber sticks between the tiers of plank. Native species of ambrosia beetles, principally *Pterocyclon mali* Fitch, had entered the wood to such an extent as to have reduced the value 50 per cent or more within a few weeks. Oak, poplar, gum, and similar woods often suffer severely from this class of injury, causing losses varying from 5 to 50 per cent. (Hopkins, 1905*a*.)

Lumber and square timbers of both soft and hard woods with the bark left on the edges are frequently damaged by flatheaded and roundheaded wood borers, which hatch from eggs deposited in the bark before or after the lumber is sawed. There are examples of losses from this character of injury amounting to from 20 to 50 per cent or more.

Telegraph and telephone poles, posts, mine props, etc., are frequently injured before they are set in the ground, especially if the bark remains on them during a few weeks after the middle of March.

SEASONED PRODUCTS IN YARDS AND STOREHOUSES.

Powder-post beetles.—Hardwood lumber of all kinds, rough handles, wagon stock, etc., made partially or entirely of sapwood, are often reduced in value from 10 to 90 per cent by a class of insects known as powder-post beetles. The sapwood of hickory, ash, and oak is most liable to attack. The reported losses from this source during the past five or six years indicate that there has been an average reduction in values of from 5 to 10 per cent or more. (Hopkins, 1903*c*, 1905*a*.)

Old hemlock and oak tanbark is often so badly damaged by various insects which infest dead and dry bark that in some tanyards as much as 50 to 75 per cent of the bark that is over three years old is destroyed. In one tannery in West Virginia it is estimated that more than $30,000 worth of hemlock bark was thus destroyed. (Hopkins, 1905*a*.)

FINISHED PRODUCTS.

The greatest loss of finished hardwood products, such as handle, wagon, carriage, and machinery stock, is caused by powder-post beetles. This is especially true of hickory and ash handles and like products in the large and small storehouses of the country, including the vast amount of material held in storage for the army and navy. When material of this kind is once attacked it is usually worthless for the purposes indicated, and therefore must be replaced with new material. In some cases losses have amounted to from 10 to 50 per cent, and it is estimated that the average losses have been as much as 10 per cent on nearly all sapwood material that has been in storage more than one year. (Hopkins, 1903*c*, 1905*a*.)

UTILIZED PRODUCTS.

Powder-post beetles, white ants, and other wood-boring insects.—The finished woodwork in implements, machinery, wagons, furniture, and the inside finish in private and public buildings are often seriously damaged by powder-post beetles, thus requiring increased demands for new material. (Hopkins, 1903*c*, 1905*a*.)

Construction timbers and other woodwork in new and old buildings are often so seriously damaged by powder-post beetles, white ants, and other wood-boring insects that the affected material has to be removed and replaced by new, or the entire structure torn down and rebuilt. (Hopkins, 1905*a*.)

Construction timbers in bridges and like structures, railroad ties, telephone and telegraph poles, mine props, fence posts, etc., are sometimes seriously injured by wood-boring larvæ, termites, black ants, carpenter bees, and powder-post beetles, and sometimes reduced in efficiency from 10 to 100 per cent.

INSECTS IN THEIR RELATION TO THE REDUCTION OF FUTURE SUPPLIES OF TIMBER.

Insects not only reduce future supplies by killing the mature trees and destroying the wood of timber that is inaccessible for utilization, but through injuries inflicted upon trees during the flowering, fruiting, germinating, seedling, and sapling periods of early growth they prevent normal reproduction and development. (Hopkins, 1904*a*, 1906*c*.)

INTERRELATIONS OF FOREST INSECTS AND FOREST FIRES.

Investigations conducted by the writer and assistants in all sections of the country during the past ten years indicate to them quite conclusively that the average percentage of loss of merchantable timber in the forests of the entire country to be charged to insects during a five or ten year period is infinitely greater than most people realize. (Hopkins, 1906*a*, pp. 4–5, 1908*b*; p. 345, 1909*b*, pp. 5, 24; Forbes, 1909, pp. 51–52.)

Losses from forest insects.—The writer estimates (p. 70) that for a ten-year period the average amount of timber in the forests of the entire country killed and reduced in value by insects would represent an average loss of $62,500,000 annually.[a]

It has been estimated (Hopkins, 1905*b*, p. 5; 1908*a*, p. 162) that the Black Hills beetle killed approximately 1,000,000,000 feet b. m. of timber during a period of ten years, which at $2.50 per thousand would amount to an average of $250,000 annually. This is merely one example of very destructive depredations by a single species of barkbeetle in a single national forest.[b] (See also p. 70.)

Prof. Lawrence Bruner, state entomologist of Nebraska, at a meeting of the American Association of Economic Entomologists, held at

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[a] *Losses from forest fires.*—It has been estimated that "on the average, since 1870, forest fires have yearly cost $50,000,000 in timber." (Cleveland, T., jr., 1909, p. 3.)

[b] It has been estimated that the losses of timber from forest fires on all of the National Forests of the United States from 1905 to 1908, inclusive, average only $165,062 annually. (Cleveland, T., jr., 1908, p. 541.)

Baltimore, Md., in December, 1908, spoke as follows: "I can agree with Doctor Hopkins that the insects are far more important in destroying our forests than fires." (Bruner, 1909, p. 53.)

Insect-killed timber as fuel for fires.—It has often happened that after insects have killed the timber over extensive areas the standing and fallen dead trees furnished fuel for great forest fires which have not only destroyed or charred the dead timber but killed the living timber and reproduction and swept on into adjacent areas of healthy timber. Indeed, abundant evidence has been found during recent investigations to indicate that some of the vast denuded areas in the Rocky Mountains and other sections of the country are primarily due to widespread devastation by insects, and that subsequent fires destroyed the timber and prevented reproduction. (Hopkins, 1906*a*.)

It is also evident that a considerable percentage of dead timber, and especially that found in coniferous forest regions, which has generally been believed to have been fire-killed is a result of primary attack by insects. This has been demonstrated in many cases by the pitch-marked galleries of the destructive barkbeetles on the surface of the wood of the old dead trees which had escaped subsequent fires.

Fire-killed timber injured by insects.—It is true that a vast amount of timber has been killed outright or has died as the direct result of forest fires, but in almost every case observed insects have contributed to a greater or less extent to the death of recently fire-injured trees which might otherwise have recovered, and especially to the rapid deterioration of the wood of a large percentage of the injured and killed trees. It is evident that in some cases fire-scorched and fire-killed timber has contributed to the multiplication of one or more of the insect enemies destructive to living timber, and thus the injury started by the fire may have resulted in a destructive outbreak of beetles. However, it is evident that this has happened only when the destructive beetle was already present in abnormal numbers in the forest surrounding the fire-swept area. Therefore, *it is believed that injuries by fire are not as a rule an important factor in contributing to subsequent depredations by barkbeetles.* Such fires, however, contribute to the multiplication of the insects which depredate on the bark and wood of dying and dead trees, so that in forested areas where fires are frequent the damage to the wood of such trees is more severe, and fewer injured trees recover on account of the abundance of secondary barkbeetle enemies which do not, as a rule, attack and kill living timber.

Destruction of insects by fire.—There is another important feature in the relation of insects and fire, in which the fire contributes to the destruction of the principal barkbeetle enemies of the living timber. This happens when the fire burns the timber while it is infested, thus effectually destroying the broods of the insects. It is perfectly plain that the dying and dead foliage of the beetle-infested trees and the dead bark on the trunks would contribute to the spreading of crown fires and thus the bark on the entire infested trunks would be sufficiently scorched to kill the insects. Therefore, complete fire control may easily contribute to more extended depredations by insects on the living timber, thus increasing, rather than diminishing, the need for insect control. However, the setting of fires or permitting them to burn for the purpose of combating insects should never be undertaken or permitted.

Durability of insect-killed timber.—Some of the matured larch trees which evidently died as a result of defoliation by the larch worm between 1881 and 1885, and which had escaped subsequent depredations by fire and wood-boring insects, were found by the writer in 1908 to be standing and sound enough to be utilized for railroad ties and many other purposes. Under similar conditions the heartwood of red spruce and white pine in the East, of Engelmann spruce in the Rocky Mountains, and of Douglas fir in the Northwest coast region have been found by the writer to be sound enough for profitable utilization for pulp wood, lumber, fuel, and other purposes from twenty to thirty years after it had been killed by insects or fire. Thus it is shown that timber killed by insects and fire would be available for utilization for many years were it not for injuries through the secondary attacks of wood-boring insects and the destruction of insect-killed timber by forest fires.

INTERRELATION OF FOREST INSECTS AND FOREST FUNGI.

Decay following injury by insects.—It is well known that the burrows in the bark and wood of living and dead trees and in the crude and finished products often contribute to the entrance of bark and wood decaying fungi. Deterioration and decay are thus far more rapid than would otherwise be possible. It is also known that trees injured and dying from primary attack by parasitic fungi are attractive to certain insects which breed in the bark and wood of sickly and dying trees, and that certain other complicated troubles affecting forest trees are the result of an intimate interrelation and interdependence of insects and fungi. There can be no doubt, however, that certain species and groups of both insects and fungi are independently capable of attacking and killing perfectly vigorous and healthy trees.

SUMMARY AND ESTIMATES RELATING TO CHARACTER AND EXTENT OF INSECT DAMAGE.

The killing of trees by insects; the damage by them to the wood of living, dying, and dead timber; the destruction of insect-killed timber by subsequent forest fires; the damage to fire-killed timber by insects; and the damage from decay resulting from insect injuries to the wood, have all been more or less continuous for centuries and are still going on in the forest and woodland areas of this country.

While these depredations are not always evident or important in all forests or localities, yet almost every year, somewhere in the forests of the country, there are widespread depredations.

In every forest and woodland there is an ever present but inconspicuous army of insects which require the bark, wood, foliage, and seeds of the various tree species for their breeding places or food. Thus, the accumulated but inconspicuous injuries wrought during the period required for the growth of a tree to commercial size go far toward reducing the average annual increment below the point of profitable investments.

The accumulated damage to crude, finished, and utilized products reduces the profits of the manufacturer, increases the price of the higher grades to the consumer, and results in an increased drain on the natural resources.

In any attempt to estimate in *dollars* or *feet, board measure*, the extent of losses or waste of timber supplies caused by insects there are many conflicting factors which contribute to the difficulty of arriving at accurate conclusions. The published information concerning the amount in board feet of standing timber in the country is admittedly only an estimate, as are also the published data relating to average stumpage value. The published statistics relating to the amount and value of forest products are of course more accurate, but until more complete data can be furnished by the forest experts on the various complicated phases of forest statistics, any figures given by the forest entomologist relating to the value of timber and commercial products destroyed or reduced in value by insects must be considered on the same basis as the other estimates, and as the best that can be presented on available evidence.

Standing timber killed and damaged by insects.—When we consider the amount of standing merchantable timber killed by insects and the amount of standing timber, living, dying, and dead, which has been reduced in quantity and value through their agency during a ten-year period, we would estimate that such timber represents an equivalent of more than 10 per cent of the quantity and stumpage value of the total stand of merchantable timber in the United States at any given time.[a] A certain percentage of such timber is a total loss because of the impossibility of utilization; but in some cases a greater or less percentage can be, and in some cases is, utilized within the period in which it is of sufficient value to yield a profitable return on the cost of logging and manufacture, although its value is greatly reduced.

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[a] The estimate of the area and stand of the present forests of the United States, as given in Circular 166 of the Forest Service, page 6, is two trillion five hundred billion feet (2,500,000,000,000) board measure. The average stumpage value has been given as $2.50 per one thousand feet b. m., making a total value of the standing merchantable timber of $6,250,000,000. Ten per cent of this amount would be $625,000,000, as the amount to be charged to insects for a 10-year period, or an average of $62,500,000 annually. As an example, it has been estimated that over 1,000,000,000 feet b. m. of timber was killed by the Black Hills beetle in the Black Hills National Forest within a period of ten years. This, at $2.50 per one thousand feet stumpage, would be an average of $250,000 annually in a single forest of 1,294,440 acres.

Reduction in the Nation's wealth.—When we consider the forest resources both in merchantable timber and young growth as an important asset of the Nation's wealth; as representing a given value to the people for direct utilization; as a cover to the soil for protection of the land from erosion; as protection of headwater streams and of game; and as contributing to the æsthetic value of health and pleasure resorts, it would be difficult indeed to estimate the amount or percentage of loss of timber or the reduction in the land values, in each case, chargeable to insects. It is plain, however, that in the aggregate it is considerably greater than when estimated on stumpage values alone.

Reduction in cash revenue.—When we consider the problem from the standpoint of direct utilization we can estimate the annual loss on a basis of mill values; but here again we meet with complications, since much of the damaged material is left standing or is discarded in the woods or at the mill without measurement. Therefore we are left to judge from our observations and knowledge of the general conditions as regards dead and damaged timber found in the forests of the country, and the information from lumbermen in different sections, as to the percentage of loss from defective timber. On this basis we can estimate that the amount of insect-killed and damaged timber left in the woods, plus the reduction in value of that utilized, to be charged to insects is not far from an equivalent of 10 per cent of the value of the annual output of forest products of all kinds, in the rough. The total value of the forest products of the United States in 1907 is given as $1,280,000,000; the losses from insect depredations would therefore represent an annual loss in a cash value of more than $100,000,000. (Hopkins, 1895*c*, 1904*a*.)

Reduction in value of finished and commercial products.—When we consider the aggregate loss to the manufacturers of the finished products, to the trade, and to the consumer from insect injuries to the wood, it is evident that it amounts to many millions of dollars in addition to the estimated loss of crude products, or at least 3 per cent of the mill value.

METHODS OF PREVENTION AND CONTROL.

The results of extensive investigations and of practical applications of the knowledge gained during recent years have demonstrated that some of the most destructive insect enemies of American forests and of the manufactured and utilized products can be controlled, and serious damage prevented, with little or no ultimate cost over that involved in forest management and business methods. (Hopkins, 1904*b*, 1905*a*, 1908*a*, 1909*b*.)

There are, of course, certain insects and certain injuries which, under present conditions and available information, can not be controlled or prevented, but it is very evident that if the information now available through the publications of the Department of Agriculture and through direct correspondence with its experts is properly utilized in the future it would result in the prevention of at least 30 per cent of the estimated annual waste of forest resources that has been caused by insects within recent years, and thus contribute greatly to the conservation of forest resources.

GENERAL PRINCIPLES OF CONTROL.

The ordinary spraying and similar methods employed in dealing with fruit and shade tree insects are, of course, not available for practical application in the case of forest trees. But there are other and less expensive methods of accomplishing the desired results.

In all efforts to control an outbreak or prevent excessive loss from forest insects it should be remembered that as a rule it is useless to attempt the complete extermination of a given insect enemy of a forest tree or forest product. Experience has demonstrated that it is only necessary to reduce and weaken its forces 75 per cent or more. It can not then continue an aggressive attack, but must occupy a defensive position against its own enemies until conditions resulting from avoidable negligence and mismanagement by the owners of the forests and manufacturers of forest products favor its again becoming destructive. Forest insects can thus be easily kept under control by good management.

The desired control or prevention of loss can often be brought about by the adoption or adjustment of those requisite details in forest management and in lumbering and manufacturing operations, storing, transportation, and utilization of the products which at the least expenditure will cause the necessary reduction of the injurious insects and establish unfavorable conditions for their future multiplication or continuance of destructive work.

It is, however, of the utmost importance that any adjustment or modification in management or business methods should be based on expert technical knowledge or advice relating to the species, habits, life history, and natural enemies of the insects involved and the essential features of the methods for their control. This should be supplemented by expert knowledge or advice on the principles of technical and applied forestry in the proper management, care, and utilization of the forest and its resources, and still further supplemented by practical knowledge and experience relating to local conditions and facilities favorable and unfavorable for success in practical applications according to the recommended method or policy of control.

As has been shown, the mature or merchantable timber is the most susceptible to injury or death from the ravages of insects. Therefore, considered from the standpoint of insect control and the prevention of one of the greatest items of loss, it is important that such matured timber should be utilized before it begins to deteriorate, or before it reaches the stage of unprofitable growth.

For the greatest success in dealing with forest insects, it must be recognized that there are certain features in the habits and seasonal history of each species which differ to a greater or less extent from those of all other species, even of the same genus; that there are certain features in the characteristics of the various species of trees which differ from those of all other species; and that as a rule it is the technical knowledge of these peculiar features or characteristics of the trees and their enemies which furnishes the clew to successful methods of control.

There are also many peculiar features in the prevailing conditions in different localities, some of them favorable, others unfavorable, for the practical application according to a given method, so that while certain general advice may apply in a broad sense and be available for utilization by the practical man, whether owner, manager, or forester, without further advice, it is often necessary to diagnose a given case before specific expert advice can be given as to the exact cause and the most effective method or policy to be adopted, just as a physician must diagnose a case of illness or injury before prescribing the required treatment for his patient.

Therefore, in a consideration of the problem as to how far the waste of forest resources caused by insects can be prevented and how far the damaged timber can be utilized, we will attempt to give only general statements based on the results of our observations relating to some of the principal kinds of loss discussed in the first part of this paper, namely, by insects which (1) kill the trees, (2) cause injuries to the wood of living timber, (3) reduce future supplies, and (4) cause injuries to the manufactured products. In addition, we will consider the utilization of natural enemies of injurious insects, the utilization of damaged timber, and the present conditions and opportunities for success in the general control of forest insects.

CONTROL OF BARKBEETLES WHICH KILL TREES.

The barkbeetles which kill trees attack the bark on the trunk and destroy the life of the tree by extending their burrows or galleries in all directions through the inner living bark. The broods of young grubs or larvæ develop within the inner bark, on which they feed.

Those of some species develop to the adult stage within the inner bark and are exposed when the bark is removed, while those of other species transform to the adults in the outer corky bark and the larvæ are not exposed when the bark is removed. Some species have two or more generations in a season or annually, while others have but one, and in a few species it requires two years for a single generation to develop. (Hopkins, 1909*b*.)

The barkbeetles of the genus Dendroctonus represent the most destructive enemies of the principal coniferous tree species of American forests, and at the same time are among the easiest of control. The general requisites for success are embodied in the following rules:

(*a*) Give prompt attention to the first evidence of a destructive outbreak, as indicated by an abnormal percentage of yellow or red topped dying trees, and especially when such trees occur in groups of ten or more or cover large areas; (*b*) secure authentic determination of the particular species of insect responsible for the trouble; and (*c*) take prompt action toward its control according to specific expert advice, published or otherwise, on the best method for the destruction of the necessary 75 per cent or more of the insects in the infested trees.

Some of the methods to be adopted to meet the requirements of various local conditions are as follows:

(1) Utilize the infested timber and burn the slabs during the period in which the broods of the destructive beetles are in the immature stages or before the developed broods emerge from the bark; or

(2) Fell the infested trees and remove the bark from the main trunk and burn the bark if necessary;[a] or

(3) Remove the infested bark from the standing timber and burn the bark when necessary;[a] or

(4) Immerse the unbarked logs in ponds, lakes, or streams, where the bark will remain soaked long enough to kill the insects; or

(5) Remove the unbarked logs or products to a locality where there are no trees liable to attack within a radius of 20 miles or more.

MAINTAINING CONTROL OF BARKBEETLES.

Future trouble of a serious nature from barkbeetles which kill trees can be prevented within a given forest or area of greater or less extent if an insect-control policy is adopted in connection with, or independent of, a fire-control policy by which groups of dying trees will receive similar prompt attention as that required for the prevention or control of forest fires.

In state and national forests.—In all forest reserves in which there is an organized force of rangers and fire wardens or patrols each officer should be furnished with instructions for the location of beetle-infested trees, and with equipment and directions for taking the necessary action whenever the conditions demand or warrant it.

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[a] If the broods develop to adults in the outer bark, it must be burned; if they develop in the inner bark and are exposed when the bark is removed, burning is not necessary. As a rule the burning of the tops to destroy the insects is not necessary.

In private forests.—Private forests should receive the same attention as public forests, but this is often far more difficult on account of intervening forests, where the owners either can not or will not give the matter the required attention. While it may be advisable to have some laws to govern the treatment of timber infested with a dangerous pest, when the owner refuses to take any action such a law should apply only to the more extreme cases or as a last resort on authoritative advice. It is probable that in most cases legislation will not be necessary, and more ultimate good will result without than with strict laws, especially when it can be made clear to the owner that his personal interests demand that he take the proper action and that, when necessary, his neighbors will render assistance, as is done in the case of a forest fire.

Inaccessible areas.—There are yet large inaccessible areas in the East and West where it is not practicable or possible at present to control the depredations by these beetles and which must therefore be left to the same natural adjustment that has been going on in all forests from their beginning. While under such natural control much of the older matured timber will be lost it will usually be replaced by young growth, either of the same species of trees or of a different species, so that under normal conditions the forest will be perpetuated; but under exceptional conditions and combinations of detrimental influences, such as secondary insect enemies, fire, drought, etc., extensive areas may be completely denuded, never to be reforested under natural conditions. Therefore it will evidently not be very long before it will pay to adopt insect-control policies even in the areas that are inaccessible for profitable lumbering.

EXAMPLES OF SUCCESSFUL CONTROL OF BARKBEETLES.

We have a sufficient number of examples of successful control of depredations by the destructive barkbeetles to demonstrate the practicability of the advice based on the results of recent entomological investigations.

Control of the eastern spruce beetle.—The control of an alarming outbreak of the eastern spruce beetle (*Dendroctonus piceaperda* Hopk.) in northeastern Maine in 1900 and 1901 was effected by the concentration of regular logging operations into the areas of infested timber and placing the logs in lakes and streams and driving them to the mills on the Androscoggin River. Thus, with little or no additional expense, there was a saving to one firm, according to its estimates, of more than $100,000.

Control of the Black Hills beetle.—An extensive outbreak of the Black Hills beetle (*Dendroctonus ponderosæ* Hopk.) in the vicinity of Colorado Springs, Colo., in 1905–6, which was threatening the living pine timber of the entire section, was brought under control through the efforts of the private owners of forests and those of forest officials in the adjoining National Forests. It was accomplished by cutting and barking about 1,000 beetle-infested and beetle-killed pine trees. The cost of the operations was largely, if not entirely, covered by the utilized felled timber, although there was considerable unnecessary expense involved through the felling and barking of trees from which the beetles had emerged and from the unnecessary burning of the bark and tops.

The successful control of another serious outbreak of the Black Hills beetle, in 1906, on an extensive private estate in southern Colorado, was effected through the efforts of the owners, who had some 500 infested trees felled and barked within the necessary period to destroy the broods. A large percentage, but not all, of the infested timber was thus treated. These operations were so successful that not a single infested and dying tree could be found when the area was inspected in 1908. In this, as in the other case, considerable unnecessary expense was involved in the burning of the bark and tops, but the value of utilizable timber was evidently more than enough to pay all expenses. It is evident that in this case a destructive invasion was prevented.

The most striking example of success relates to a large estate near Idaho Springs, Colo., and in the adjoining Pike National Forest. In May, 1907, it was found that some 63,000 feet of standing timber on the estate was infested by the Black Hills beetle, and the owner was advised by the Bureau of Entomology that unless the ravages were checked at once the beetle would kill the timber not only on this estate but that on the adjoining estates and National Forest, and that therefore radical action should be taken according to the recommendations and detailed instructions given relating to a necessary control policy. No action was taken, however, before the first of the following July, and therefore not in time to prevent the broods of beetles from swarming from the infested trees and extending their ravages. In December, 1907, another examination of the timber was made, and it was found that instead of 65,000 feet of timber in the old infestation there was nearly four times as much timber involved in the new, or over 250,000 feet. The owner was again notified of the serious character of the outbreak, and further suggestion made that if the logs from the infested trees were converted into lumber and the slabs burned before May, 1908, it would result in the protection of the remaining living timber. Immediate steps were then taken by the owners to carry out the original recommendations. An expert in locating infested timber, working under instructions from this Bureau, gave instructions to the manager of the estate in locating and marking the infested trees and in the essential features in the methods of utilization to destroy the necessary number of beetles; he also marked infested timber on an adjoining estate and on the National Forest. Five months later, in May, 1908, this expert reported that the larger clumps of infested trees on the estate had been converted into lumber and the slabs burned, and that the marked trees on the adjoining estate and National Forest had been cut and barked. In November, 1908, another inspection of the forest on the estate and surrounding area was made by the expert, and on December 1 he reported as follows:

> Nothing could be more satisfactory than the results obtained by the cutting of the infested timber on the estate. Your recommendations and instructions submitted to the owner, and carefully followed by the manager of the estate, have clearly demonstrated that insect infestation can be controlled, and at no expense to the owner of the timber involved; in fact a very satisfactory price was realized, resulting in a net profit, I understand, of over $5 per thousand feet, board measure, on the 240,000 feet cut. This, of course, does not include the profit of the milling operations, but for the logs sold at the mill, after deducting the expenses of cutting and logging. The sawmill was owned and operated by an Idaho Springs firm, and the manufactured article sold in that town. I spent six days on the estate, November 18 to 23. After a very thorough examination of the timber, I found only three infested trees, isolated individuals, and over a mile from where the large clumps of infested trees were cut. With the exception of those three trees, there is no new infestation on the estate. I also examined the adjoining lands, but no new infestation was observed. The infested trees which I marked in December, 1907, had been cut and barked. On the Pike National Forest, contiguous to the first mentioned estate, where you will remember I marked some clumps of infested trees, no new infestation was found, not one tree.

This most gratifying result demonstrated two important things: One, that an extensive outbreak by the most destructive barkbeetle enemy of the pine timber of the central Rocky Mountain forests, involving in this case more than 1,000 infested trees, can be controlled without expense, and even at a profit, whenever the conditions are favorable for the utilization of the infested timber; the other, that the essential details of the recommendations and expert advice, based on the results of scientific research, can be successfully applied by a manager of a private forest or by the rangers of national and state forests. It also indicates quite conclusively that the widespread depredations in the Black Hills National Forest could have been prevented with very little expense to the Government if the matter had received prompt attention in 1901, when the first investigations were made and essentially the same recommendations submitted. But, through the lack of public appreciation of the importance of the problem at the time, and the lack of sufficient authority and funds later, the outbreak was allowed to extend beyond practical control, and in consequence a large percentage of the timber of the entire National Forest has been killed. There were, then, no forcible examples of the practical value of such recommendations based on scientific research, and no other argument was effective in arousing public interest in the threatening character of the outbreak or confidence in scientific advice or methods of control. Now we have several examples demonstrating the practicability of forest-insect control in America which should lead to confidence in the results of scientific research as a basis for success in practical application.

Control of the hickory barkbeetle.—The complete control of the hickory barkbeetle (*Scolytus quadrispinosus* Say), which threatened the total destruction of the hickory trees on Belle Isle Park, at Detroit, Mich., in 1903, was effected by felling and removing the infested trees and converting them into merchantable products, all without cost to the park commission. (Hopkins, 1904*b*.)

CONTROL OF INSECTS WHICH CAUSE DEFECTS IN LIVING TIMBER.

The class of insects which causes defects in the wood of living timber can be controlled to a greater or less extent, depending upon local conditions, and a large percentage of the losses prevented through the adoption of certain requisite details in forest management. Of these the following are especially important:

(1) The utilization of all of the defective and infested timber that will pay expenses for manufacture into merchantable products, such as lumber, cordwood, etc.

(2) The burning of infested timber and waste material not available for use, including dead standing and fallen timber, to remove the breeding places of insects like the oak timber worm and the chestnut timber worm, which go from the dead to the living timber.

(3) The prevention of wounds of any kind in the bark of living trees.

(4) The prevention of future losses by the practice of improved forestry methods which will eliminate favorable conditions for injury and contribute to a perpetual supply of vigorous, healthy timber to be utilized before it passes the stage of profitable increment.

PREVENTION OF INJURY TO DYING AND DEAD TREES.

A large percentage of the injury to the wood of insect, fire, and lightning killed trees and those killed or dying from injuries by storms, disease, etc., can be prevented as follows:

(1) By the prompt utilization of such timber within a few weeks or months after it is dead or found to be past recovery.

(2) By removing the bark from the merchantable portions of the trunks within a few weeks after the trees are dead (the work to be done either before or after the trees are felled).

(3) By felling the trees and placing the unbarked logs in water.

(4) By the adoption of a system of forest management which will provide for the prompt utilization of all trees which die from any cause.

PREVENTION OF LOSS FROM INSECT INJURIES TO NATURAL AND ARTIFICIAL REPRODUCTION.

The successful control of the insects which destroy or prevent the normal development of natural reproduction is a far more difficult problem than that presented by other classes of insect injuries, but in this as in the others a great deal can be accomplished toward preventing the reduction of future supplies.

Much can be accomplished in nurseries and small plantations by the adoption of the ordinary methods of controlling farm and orchard insects, but in the natural forests reliance must be placed largely on systems of forest management which will bring about unfavorable conditions for the work of the more important enemies. (Hopkins, 1906*c*.)

Utilization of Immune and Resistant Varieties and Races of Trees.

Certain individuals representing varietal or racial forms of trees of a given species are sometimes found to be either immune or decidedly more resistant to the insects which are destructive or seriously injurious to the life or wood of other individuals or varieties of the same species. This fact suggests the importance of recognizing the well-known principle of improvement by selection. Thus, selecting seed or cuttings from such immune and resistant trees for artificial propagation, or taking great pains to leave such trees in commercial or selection cuttings for natural reproduction, will undoubtedly be an important step toward providing against damage and loss in the future. (Hopkins, 1906*b*, 1907*a*, 1907*c*, 1907*d*.)

PREVENTION OF INSECT INJURIES TO FOREST PRODUCTS.

The problem of artificial control and prevention of insect injuries to forest products offers less difficulties perhaps than that relating to many other branches of the general subject of forest-insect control. In most cases the principle of prevention is the only one to be considered, since the damage is done soon after the insects enter the wood, and therefore it can not be repaired by destroying the enemy.

Crude Products.

The proper degree of moisture found in the bark and wood of newly felled trees, saw logs, telegraph poles, posts, and like material, cut in the fall and winter and left on the ground or in close piles during a few weeks or months in the spring and summer, or during the period when the particular species of injurious insects are flying, are some of the conditions most favorable to attack. The period of danger varies with the kind of timber and the time of the year it is felled. Those felled in late fall and winter will generally remain attractive to ambrosia beetles and adults of round and flat headed borers during March, April, and May. Those felled during the period between April and September may be attacked in a few days after they are felled, but the period of danger from a given species of insect may not extend over more than a few weeks. Thus certain kinds of trees felled during certain seasons are never attacked, while if they are felled at other times and seasons the conditions for attack may be most favorable when the insects are active, and then the wood will be thickly infested and ruined. The presence of bark is absolutely necessary for successful infestation by most of the wood-boring grubs, because the eggs and young stages must occupy the inner and outer portions before the latter can enter the wood. Some ambrosia beetles and timber worms will, however, attack barked logs, especially those in close piles or otherwise shaded or protected from rapid drying. A large percentage of the injury to this class of products can be prevented, as follows:

(1) Provide for as little delay as possible between the felling of the tree and its manufacture into rough products. This is especially necessary with trees felled from April to September in the region north of the Gulf States and from March to November in the latter, while the late fall and winter cuttings should all be worked up by March or April.

(2) Do not leave the round timbers in the woods or on the skidways during the danger period, or, if this is unavoidable, take every precaution to facilitate the rapid drying of the inner bark by keeping the logs off the ground, in the sun, or in loose piles, or else, if possible, the opposite extreme should be adopted and the logs kept in water.

(3) Remove the bark within a few days after the trees are felled, from poles, posts, and other material which will not be injured by checking or season cracks.

(4) Take advantage of the proper months or seasons in which to fell or girdle different kinds of trees to avoid danger.

Damage to products cut from saplings and left with the bark on can be prevented by transporting the material from the woods soon after it is cut, so that it will not be left in piles or bundles in or near the forest during the season of insect activity. Damage may also be prevented by care not to leave the material stored in one place for several months.

Pinhole damage to stave and shingle bolts cut during a warm season can be prevented by removing the bark from the timber as soon as it is felled and by converting the bolts into the smallest practicable dimensions and piling them in such a manner as to facilitate rapid drying.

Damage to unseasoned handle and wagon stock in the rough can be prevented by taking special precautions to provide against the same favorable conditions for attack as mentioned in connection with round timbers. This is especially necessary with hickory and ash if cut during the winter and spring.

Damage to pulpwood and cordwood can be prevented to a great extent by placing the sticks of wood in triangular or crib piles immediately after they are cut from the trees, especially if the timber is cut during the danger period or must be held for a few months during the warm season. Peeling or splitting the wood, or both, before it is piled will also provide against damage from insects.

Manufactured Products.

UNSEASONED PRODUCTS.

Freshly sawed hardwood lumber placed in close piles during warm, damp weather in the period from July to September, inclusive, presents the most favorable conditions for injury by ambrosia beetles. In all cases it is the moist condition and retarded drying of the lumber which induces attack. Therefore any method which will provide for the rapid drying of the lumber before or after piling will tend to prevent loss. It is important, also, that heavy lumber should, as far as possible, be cut only in the winter and piled so that it will be well dried out before the middle of March.

The damage to lumber and square timber when the bark is left on the edges or sides can be prevented by removing the bark before or immediately after the lumber is sawed, or by sawing and piling the material during the winter, or if sawed at other times it should be piled so that rapid drying will be facilitated.

SEASONED PRODUCTS.

Unfinished seasoned products.—Injury by powder-post beetles to dry hardwood lumber and other material in stacks or storehouses can be prevented as follows:

(1) Have a general inspection of the material in the yards and storehouses at least once a year, preferably during November or February, for the purpose of (*a*) sorting out and destroying or otherwise disposing of any material that shows the slightest evidence of injury, as indicated by the presence of fine powdery boring dust, and (*b*) sorting out and destroying all old and useless sapwood material of any kind that will offer favorable breeding places for the insects.

(2) Prevent the introduction into the lumber yards or storehouses of any infested material, remembering that the insect may be thus distributed to or from all parts of the world.

(3) Adopt a system of classification of all dry or seasoned hardwood stock which will provide for (*a*) the separation of the pure heartwood material from the pure and part sapwood material; (*b*) classification of all kinds of wood most liable to attack, such as hickory, ash, oak; (*c*) the successive utilization or sale of the older material (remembering that material one year old or over is far more liable to injury); (*d*) providing against the accumulation of refuse material in which the insects could breed; and (*e*) treating the best material with linseed oil or kerosene to prevent attack.

Finished seasoned products.—Damage to finished handles, oars, spokes, rims, hubs, wheels, and other unpainted wagon, carriage, machinery, and implement stock in factories, wholesale and retail storehouses, and army and navy stores can be prevented by the adoption of the same general rules as those given under rough products. In addition, damage can be controlled and prevented in the following manner:

Sort out and (*a*) destroy all articles showing the slightest evidence of powder-post injury, or (*b*) treat with kerosene oil such infested and slightly injured articles as may be tested for required strength and found to be of sufficient value for retention, placing the same in quarantine for a sufficient time to determine whether the treatment is successful.

Damage by powder-post insects to many kinds of articles can be prevented and at the same time the material otherwise benefited by treating the sapwood with linseed oil or kerosene, either by immersing it in the oil or by applying the oil with a brush, the application to be made as soon as possible after the articles are finished from recently seasoned, uninjured stock.

PAST AND PRESENT CONDITIONS OF POWDER-POST INJURY.

Up to 1906 there were a great many reports of extensive losses of valuable material from the ravages of powder-post beetles which were seriously affecting all industries involved in the manufacture, sale, and utilization of the classes of hardwood products affected by them. In response to these reports and accompanying appeals to the Department of Agriculture for information on causes and remedies, the problem was thoroughly investigated and specific advice and instructions relating to practical methods of control and prevention have been widely disseminated, both through publications of the Department and special correspondence.

Reports of present conditions from our principal correspondents, together with the less frequent requests for advice, indicate that the disseminated information has been extensively utilized and that it has been worth many millions of dollars toward eliminating the losses and reducing the drain on the limited supply of the kinds of timber required to replenish the damaged and destroyed material.

The army and navy stores of handles, tent poles, wheelbarrows, oars, and many other hardwood articles have suffered severely from powder-post damage, involving an enormous loss, but the carrying out of the information already supplied has evidently contributed greatly toward the elimination of this source of loss to the Government.

TAN BARK.

Damage to hemlock and oak tan bark by the class of insects which in some cases has been so destructive to these products in the past can be easily prevented without cost, as follows:

(1) Utilize the bark within three years from the time it is taken from the trees.

(2) Prevent the accumulation in the yards and store-sheds of old bark and waste material in which the insects can breed.

These simple methods have been extensively adopted since their recommendation in correspondence and publications between about 1894 and 1904, and afford one of the most striking examples of the value of expert information on the peculiar habits of insects and of how millions of dollars can be saved without cost through a simple adjustment in methods of utilization.

UTILIZED PRODUCTS.

Damage and loss from insect injuries to timber and other woodwork in structures of various kinds, to telephone and telegraph poles, posts, railroad ties, mine props, etc., can be prevented to a large extent through the adoption of the proper methods of management or of treating the material with preservatives before and after it is utilized.

TIMBERS AND WOODWORK IN STRUCTURES.

Injuries to timbers and woodwork in dwellings, outbuildings, bridges, etc., by powder-post insects can be prevented as follows:

(1) Use nothing but heartwood for the concealed parts most liable to damage.

(2) If it is necessary to use all or part sapwood material, attack can be prevented by treating the sap portions with kerosene, coal tar, creosote, or linseed oil. Facilities for future treatment can be provided wherever the rough or finished woodwork is exposed, as in outbuildings, bridges, etc., if care is taken to expose the sapwood portions.

(3) If the untreated timbers and woodwork in old buildings show evidence of attack, the affected portions should be given a liberal application of kerosene.

Damage by white ants, or termites, can often be prevented in the following ways:

(1) By the use of nothing but sound wood for underpinning and foundation timbers and the removal of decaying timbers from old structures.

(2) By preventing moist conditions of the wood in any part of the structure and especially that in foundation timbers.

(3) By the treatment of timbers necessarily exposed to moist conditions with creosote, zinc chlorid, corrosive sublimate, etc.

(4) If the timbers become infested, further progress of insect damage can be prevented by removing the badly damaged parts and soaking the remainder with kerosene, fumigating with bisulphid of carbon, and by removing any adjacent decaying or other wood in which the insects have been breeding or may breed, such as logs, stumps, etc.

Log cabins and rustic work.—Damage by bark and wood boring insects to the unbarked logs and poles used in rustic cabins, summer houses, fences, etc., can be largely prevented by cutting the material in October and November and utilizing it at once, or by piling it off the ground or under cover in such a manner as to offer the best facilities for the rapid and thorough drying of the inner bark before the middle of March or the 1st of April following. If these necessary precautions are not taken, and there is evidence that insects are at work in the bark and wood, the damage can be checked by injecting bisulphid of carbon through natural or artificial openings in the affected bark, and immediately stopping these and other openings with putty or a similar substance.

Poles, posts, piles, ties, mine props, and similar products.—Insect damage to poles, posts, and similar products can be prevented to a greater or less extent by the preservative treatments which have been tested and recommended by the Forest Service for the prevention of decay. These should be applied before the material is utilized for the purposes intended, or, if it be attacked after it has been utilized, further damage can be checked to a certain extent by the use of the same substances.

It is often of prime importance to prevent injury from wood-boring insects, for the reason that such injuries contribute to more rapid decay. Therefore anything that will prevent insect injury, either before or after the utilization of such products, will contribute to the prevention of premature deterioration and decay.

UTILIZATION OF NATURAL ENEMIES AND FACTORS IN THE CONTROL OF INJURIOUS INSECTS.

Were it not for the natural checks and natural factors of control of some of the more destructive insect enemies of forest trees and forest products, artificial control would in many cases be impossible, and the depredations would evidently be far more continuous and complete. These natural factors in the control of the depredating insects consist of parasitic and predatory insects, diseases of insects, birds, adverse climatic conditions, etc. While one or more of these beneficial factors exert a continuous and powerful influence toward the prevention of a more extensive waste of forest resources, it has been repeatedly demonstrated that they can not be depended on to prevent widespread devastations or to otherwise work for the best interests of the private or public owner by protecting the best trees and the best tree species. The insects and birds which prey upon the depredating insects also have factors to contend against, consisting of insects, birds, diseases, and climatic conditions. Therefore under normal conditions the tendency is toward the preservation of a balance between the warring factors, but frequently the enemies of the trees get the ascendancy and take on the character of an invasion, which may continue for two or three or even ten years before the balance is again adjusted through the influence of the natural enemies or diminished food supply. Thus a vast amount of timber or of a given forest product may be destroyed before the factors of natural control can prevail.

It is evident that the most effective utilization of the factors of natural control will be through the alliance with them of the owner of the forest in the artificial reduction of the enemies of the trees rather than by efforts to make the natural enemies of the injurious insects his allies through artificial introduction or dissemination. The former is accomplished by the adoption of methods of combating the invaders which will reduce and weaken their forces below their power of prosecuting aggressive movements and attacks, or, as previously stated, to reduce their numbers to the point where they must occupy a defensive position against their natural enemies and be dependent for their supplies of food and breeding places upon that furnished through avoidable mismanagement of the forests and manufacturing operations. Thus the owner of the forest can contribute greatly toward the preservation of a balance which will be to his material benefit. On the other hand, he may in the future, as in the past, contribute greatly to the multiplication of the depredating insects and to greatly increased losses caused by them, through neglect or a disregard of available information on the fundamental principles of insect control in the management of forests and manufacturing enterprises.

Beneficial Insects.

The beneficial insects comprise those which are internal or external parasites of the immature or mature stages of the injurious insects, and predators which feed on the young or adults of insects either before or after they make their attack on the trees or products. These two beneficial factors are doubtless far more effective in the long run than any other agencies of natural control. Yet they, in combination with all other factors, can not be always relied upon to render continued and efficient control. They can, however, be relied upon to respond to artificial assistance in reducing the numbers of the depredators.

Beneficial Diseases of Insects.

It is very evident that the parasitic fungi and bacteria which sometimes cause epidemics among injurious insects often exert a powerful influence toward the control of extensive outbreaks or invasions of insect enemies of forests. Indeed, it appears that the greatest service rendered by this class of natural enemies is in the frequent sudden appearance of an epidemic which kills off a destructive species of insect after the latter has increased to such numbers and extended its depredations over such vast areas as to be far beyond the control of man or his insect and bird allies. Numerous examples of this kind of natural control are found in the sudden ending of widespread depredations by various species of caterpillars and sawfly larvæ which defoliate deciduous and coniferous trees. As a rule, however, the beneficial effects of the diseases of insects prevail only after the injurious insects have increased to excessive numbers. Therefore this factor of insect control can not be depended upon to hold the insects in check or prevent outbreaks. The fact, however, that it operates on a class of insect enemies of the forest (defoliators) which at present can not be controlled by any known artificial methods renders the services of the diseases all the more valuable.

It is believed that with further knowledge of nature's method of propagating, perpetuating, and disseminating the diseases which cause epidemics among insects, they may be utilized more or less successfully through artificial propagation and dissemination to prevent threatened invasions of defoliating insects.

Beneficial Birds.

It is very evident that certain kinds of birds, such as woodpeckers, render valuable service toward the natural control of destructive bark and wood boring insects. They appear to render the greatest service, however, where but few trees are being killed or injured, because their concentrated work on such trees may contribute toward the prevention of an abnormal increase of the insects. They also render some service as allies of the other beneficial factors which assist in artificial control. It is evident, however, that where many hundreds or thousands of trees are being killed the comparatively limited number of birds in any forest under the most favorable conditions could have little or no beneficial effect. Therefore, while the birds should be classed among the valuable friends of the forest, and should be protected, it is plain that they can not, even with the utmost protection, always be relied upon to protect the forest against destructive ravages of insects.

We must remember, in this connection, that there are complicated interrelations between birds, injurious insects, and beneficial insects which do not necessarily always operate to the benefit of the forest. In fact, it may sometimes be quite the reverse. Therefore, in order to derive the greatest benefit from the conflict between the birds, the insect enemies of the trees, and the insect friends of the trees, we must utilize our knowledge of the factors which are contributing toward the preservation of a balance, so that whenever the enemies of the forest threaten to get beyond natural control we may enter the field through artificial means and endeavor to force them back to their normal defensive position.

Beneficial Climatic Conditions.

The benefits to be derived from climatic conditions which are detrimental or destructive to insect enemies of the forest, while sometimes very great, are necessarily unreliable, and thus can not be depended upon to assist in artificial control. In fact, the very condition which may contribute to the destruction of one depredator may favor the multiplication of another.

UTILIZATION OF WASTE CAUSED BY INSECTS.

When we come to consider the vast amount of standing timber in the forests of the country which has been injured or killed by insects, and will go to waste if it is not utilized within a limited period, we realize that there are great possibilities in its utilization as a means of preventing the reduction of future supplies of living healthy timber. It is all the more important that the insect-infested timber should be utilized, because in so doing we can contribute more perhaps than in any other way to the reduction of the insects to or below their normal numbers, and thus provide against serious injury in the future, as well as to the maintenance of control.

PRESENT CONDITIONS AND OPPORTUNITIES.

Unfortunately, the examples of management, or rather mismanagement, which are contributing to an extension or increase of waste are far in excess of those which under proper management are contributing to the reverse. This is due in a large part to the conditions that have prevailed in American forests in the past that have rendered it impracticable to adopt improved policies of forest management, but at present it is largely due to a lack of appreciation of the importance of the subject, and of the opportunities to prevent such losses, when it is not only practicable but possible to do so, and when it will, at the same time, yield large returns on the necessary additional expense. This is especially true in thousands of farmers' woodlots and private holdings in the States east of the Mississippi River, in which from 25 to 90 per cent of all of the serious injury of the past can be prevented in the future with little or no additional expense over that required for ordinary good forest management.

FOREST ENTOMOLOGY AS APPLIED TO AMERICAN FORESTS.

It is only within the past eleven years that any attempt has been made toward a systematic investigation of the insect enemies of the forest trees and forest products of the entire country. The state of knowledge of the subject previous to that time can be judged by the fact that a number of the most destructive enemies of forest trees are found to be new to science, and that nothing whatever was known of the habits and seasonal history of a large number of the more important known species which are common enemies of forest trees and forest products, while scarcely anything was known in regard to practical methods of controlling the principal enemies of the forest and its products, or of preventing losses from their ravages as applied to conditions in this country.

PRESENT KNOWLEDGE.

Within the past ten years forest-insect investigations have been conducted by the Bureau of Entomology of the Department of Agriculture in all of the principal forest regions of the United States, and have led to the following results:

Results of investigations.—Satisfactory progress has been made toward the attainment of some of the fundamental objects of the investigations, one of which has been the laying of a substantial foundation for forest entomology in this country on which future progress can be made along the lines of acquiring, disseminating, and applying information of immediate practical value in the protection of our forest resources.

Acquired and new information.—The principal insect enemies of the forests and forest products of North America have become known, and the general character and extent of their depredations have been ascertained.

The more important facts in the life history, habits, and practical methods of control relating to some of the more destructive insects have been determined.

A mass of original data has been collected relating to forest insects in general, including not only those which are destructive or injurious, but also those which are beneficial or neutral in their relation to the forest, as represented by a collection of more than a million specimens of insects and their work.

As a direct result of the investigations of forest insects during the past six years, at a cost of less than $53,000, there has been accumulated a reserve fund of information now available through publications, correspondence, and field demonstrations which, if properly utilized for practical application, would evidently prevent from 10 to 30 per cent of the annual losses at a very small cost.

Disseminated information.—In addition to information disseminated in all sections of the country through correspondence, lectures, demonstrations, exhibitions, etc., the published information, based on results of investigations conducted by the West Virginia Agricultural Experiment Station and by the Bureau of Entomology of the U. S. Department of Agriculture during the past eighteen years, is represented by over 1,300 pages, 99 plates, and 340 figures. (See list of publications.)

NEEDS.

The work that has been done is only a beginning in the vast field of forest entomology. There is need of more systematic work (or so-called pure science) on the different stages of the thousands of species of injurious and beneficial insects involved. *This is absolutely necessary in order to have the further scientific basis of facts on which to build the structure of complex details necessary to success in practical application in its broadest sense.*

There is need of further detailed study of habits and seasonal history of the species of injurious and beneficial insects, as well as of the local and other conditions favorable and unfavorable for their multiplication and work.

Further information is desirable on the principal factors of natural control of injurious insects, in order that it may be better utilized to facilitate artificial control.

There is special need of more general information and public interest in the subject of losses from insect depredations on standing timber and timber products, and a better realization of the possibility and practicability of preventing losses.

Looking to this end, there is need of further demonstration and educational work along the lines which will bring the matter to the attention of the man in the woods, sawmill, factory, or trade who is in direct touch with the local conditions and business methods.

There is a special need of more experts in forest entomology, and there will be an increasing demand for such experts in the future, to organize and take charge of insect-control policies in state forests, in public parks, in the more extensive private or commercial forests, and in extensive manufacturing enterprises, and to give instructions to students in forestry schools and forestry departments in state and other institutions of learning.

The need of trained and experienced experts in forest entomology for all of this class of work can not be too strongly urged. There is perhaps no branch of economic or applied science which requires more technical knowledge and practical experience as a basis for proper investigations and authentic instructions and advice than forest entomology, and there is perhaps no other feature in the science and practice of forestry in which advice and application based on insufficient knowledge is so dangerous.

There is quite a general recognition of the importance of guarding against contagious diseases, of the necessity of consulting a physician in cases of serious illness, and of relying on authorized pharmacists to fill the prescription, and then administering the prescribed treatment according to directions, but it is a notable fact that there are comparatively few persons who, even when deeply interested in preserving the health of the forest, have heretofore recognized the importance of guarding against insect epidemics or of consulting an expert forest entomologist in case of a threatened or existing outbreak. It has often happened that when such advice has been sought and received, the treatment was not administered according to the recommendations but changed to suit the ideas of some one entirely ignorant of the facts and principles upon which it was based. This has often resulted not only in failure to accomplish the desired end, but has contributed to an aggravation of the trouble and increased loss. The determination of the cause of specific troubles affecting the individuals of a given species of forest tree or an injury to a given type of product is just as complicated and requires the same elements of experience, training, and skill as that required for the determination of the cause of a given disease or the character of a given injury affecting man. It is just as important to know the cause or character of injury in the former as it is in the latter, in order to prescribe the specific treatment which will yield the desired results.

Therefore, in order to make the best progress toward preventing future waste of our forest resources from depredations by insects, every one interested in the subject, and especially those in authority in the public and private institutions of investigation and learning, should see to it that the instructions to students and the information given out to the public is not only the best available but that it is limited to the range of expert knowledge of the subject possessed by the instructor or investigator.

ELEMENTARY AND TECHNICAL KNOWLEDGE OF FOREST ENTOMOLOGY FOR THE FORESTER.

While it may be desirable that every professional forester should have an expert knowledge of forest entomology, it is rarely possible, even under exceptionally favorable conditions, for him to acquire more than the necessary elementary knowledge, and even this has not been possible under the conditions which have necessarily prevailed in the forest schools, and in the practice of forestry, in this country. Little or no time has been available for acquiring the necessary information from subsequent study and practical experience. Therefore this feature in the education of the American forester has been practically neglected.

PRESENT REQUIREMENTS OF INSTRUCTION.

As long as expert forest entomologists and authentic text-books based on American insects and conditions are not available for giving a complete course in technical and applied forest entomology the requirements of such a course should be limited to instruction in elementary entomology, and in elementary principles of applied forest entomology, which will give the necessary foundation for intelligent observations and utilization of available information as required in future practice.

CONCLUSION.

There is conclusive evidence that insects have been in the past, and are now, important factors in the waste and reduction of timber supplies, and will continue to be such in the future (pp. 57–58).

They attack perfectly healthy trees of all ages and kill them (p. 58).

They have at times killed a large percentage of the best timber over thousands of square miles of heavily forested lands (pp. 58–60).

They reduce the value of living timber and that of crude and finished products (pp. 60–66).

The accumulated evidence through many years of investigation and observation in the principal forest areas of the entire country by the writer and the field assistants in forest insect investigations furnishes the basis for the following summarized statements and estimates:

A large percentage of pine and spruce timber was killed by the southern pine beetle in 1890–1892 over an area of 75,000 square miles in West Virginia, Maryland, Pennsylvania, Virginia, and North Carolina (p. 58).

Billions of feet of matured spruce have been killed by the eastern spruce beetle during the past half century in the northeastern United States and southeastern Canada (p. 58).

A large percentage of the matured Engelmann spruce of the Rocky Mountains region has been killed by the Engelmann spruce beetle within the past fifty years (p. 59).

A large percentage of the pine timber of merchantable size in the Black Hills National Forest and other national and private forests of the central Rocky Mountains region has been killed during the past ten years by the Black Hills beetle (p. 59).

A large percentage of the best matured pine timber of the region north and west of Colorado and Utah has been killed within the past twenty years by the mountain pine beetle and the western pine beetle (p. 59).

A large percentage of the matured Douglas fir, or red fir, of the Rocky Mountains region has been killed by the Douglas fir beetle (p. 59).

The supply of hickory timber in the forests and woodlots of the States east of the Mississippi River has been greatly reduced by the ravages of the hickory barkbeetle (p. 60).

Practically all of the matured eastern larch has been killed over vast areas in the northeastern United States and southeastern Canada by the larch worm and eastern larch beetle (p. 60).

The wood of living timber has been rendered defective by wood-boring insects to such an extent as to reduce the value of a vast amount of standing timber from 50 to 75 per cent (p. 60).

Rapid deterioration of the wood of dying and dead trees has been caused by wood-boring insects, often amounting to from 25 to 100 per cent during the period in which it would otherwise be available for utilization (p. 62).

Crude manufactured and finished forest products have been damaged by insects to such an extent as to cause an estimated average annual loss of 10 per cent of its mill value (pp. 64–67).

Insects are the cause of greatly reducing our forest resources by killing the inaccessible timber; by reducing the quantity through injuries to the wood of living and dying timber; by preventing normal reproduction and development of future supplies, and through destroying forest products.

GENERAL ESTIMATES OF AMOUNT OF DAMAGE CAUSED BY FOREST INSECTS.

The results of extensive observations during the past ten years in the principal forested areas of all sections of the country, and during an additional eight years in West Virginia, indicate to the writer that the amount of standing timber killed by insects, together with the standing living, dying, and dead timber reduced in quality and value by them in the forests of the country, to be found at any given time, has been not far from 10 per cent of the total stand of merchantable-sized timber (pp. 70–71).

Considering the forest in its broadest sense as a source of national wealth of a given value for all purposes, including direct utilization, protection of land from erosion, protection of headwater streams, protection of game, and as contributing to the real and æsthetic value of health and pleasure resorts, it is evident to the writer that the total damage caused by insects has been equivalent to an average additional 5 per cent of the value of the merchantable-sized timber of the entire country (p. 71).

Considering the problem of insect damage to standing timber and crude products on the basis of direct utilization of the forest resources, it is evident that the reduction in value below that of healthy timber or sound products at the time of utilization, including losses from handling defective material, has amounted to an equivalent of at least 10 per cent of the average annual mill value of the aggregate output of forest products of all kinds. This, of course, includes the killed and damaged merchantable-sized timber considered under the estimate relating to standing timber, given above. Since the killed and damaged standing timber is involved in any given annual output, this estimate on a basis of utilization represents more nearly a direct reduction in cash values (p. 71).

The writer estimates that the annual loss caused by insects injurious to finished and utilized products, including the consequent increased drain on the forest resources to replace that prematurely destroyed by insects, is equivalent to at least 3 per cent of the original or mill value.

HOW LOSSES CAN BE PREVENTED.

The results of extensive investigations and of practical applications during recent years have demonstrated that some of the most destructive insect enemies of American forests and of manufactured and utilized products can be controlled and serious damage prevented with little or no ultimate cost over that involved in good forest management and business methods.

It is evident that if the information now available through publications of the Department of Agriculture and through direct correspondence with its experts is properly utilized in the future it will result in the prevention of an equivalent of at least 30 per cent of the estimated annual waste of forest resources that has been caused by insects within recent years and thus contribute greatly to the conservation of the forest resources. This can be accomplished as follows:

(1) By the adoption or adjustment of certain requisite details in forest management, in lumbering and manufacturing operations, and in storing, transporting, and utilizing the products which, at the least expense, will bring about the necessary reduction of the injurious insect and unfavorable conditions for their future multiplication or destructive work.

(2) By the adoption of policies of control, based upon expert technical knowledge or advice relating to the species, habits, life history, and natural enemies of the insects involved, and methods for their control, supplemented by expert knowledge or advice on the principles of technical and applied forestry in the proper management, care, and utilization of the forest and its resources and still further supplemented by practical knowledge and experience relating to local conditions and facilities favorable and unfavorable for successful application according to a given method or policy of control.

(3) By reliance on technical advice furnished by recognized experts in forest entomology and forestry as a basis for success in practical application by the owner or forester.

(4) By utilization of so-called matured timber, and especially dense or pure stands of such timber, thus removing one of the favorable conditions for rapid deterioration through attacks by wood-boring insects or death through the attack of destructive bark-boring or defoliating insects.

(5) By the utilization of a knowledge of the principles of natural control as a means of contributing to the efficiency of artificial control.

(6) By prompt recognition of the first evidences of the work or destructive outbreaks of the principal insect depredators, by authentic identification of the species involved, and by prompt action in adopting the proper method or methods of control for the prevention of losses.

It should be remembered that as a rule it is useless to attempt the extermination of an insect enemy of the forest or its products. It is only necessary to reduce and weaken its forces at least 75 per cent, so that it can not continue an aggressive invasion, but must occupy a defensive position against its own enemies and become dependent upon favorable conditions resulting from avoidable negligence and mismanagement by the owners of the forests and the manufacturers of forest products.

While beneficial insects, beneficial birds, and beneficial diseases exert a continuous and powerful influence toward the prevention of a more extensive waste of forest resources, it has been repeatedly demonstrated that they can not be depended upon always to prevent widespread devastations or otherwise to work for the best interests of the private or public owner by protecting the best trees and the best tree species.

The best way to utilize the factors of natural control is to become their allies and assist in the reduction of the enemy, rather than to try to make them our allies through artificial introduction or dissemination.

A large percentage of the waste caused by insects can be prevented by the utilization of infested material, and at the same time, without additional expense, this will contribute greatly to the control of insects which cause such waste and also prevent injuries and depredations in the future.

Under past conditions the poor management or neglect of the average forest has contributed to the increase of depredations by insects.

Under present conditions of better management of local forests and of the more progressive manufacturing enterprises much is being accomplished toward the reduction of losses. In the average forest, and in the average business enterprise dealing with forest products, present conditions are little better than in the past. This is largely due to a lack of appreciation of the importance of the subject and failure to realize the opportunity and practicability of preventing a large percentage of the loss.

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 83, Part I.
L. O. HOWARD, Entomologist and Chief of Bureau.

PRACTICAL INFORMATION ON THE SCOLYTID BEETLES OF NORTH AMERICAN FORESTS.

I. BARKBEETLES OF THE GENUS DENDROCTONUS.

BY

A. D. HOPKINS, Ph. D.,
In Charge of Forest Insect Investigations.

Issued October 11, 1909.

WASHINGTON:
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1909.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., March 31, 1909.

Sir: I have the honor to transmit herewith manuscript of the first part of a proposed bulletin of this bureau, to be entitled "Practical Information on the Scolytid Beetles of North American Forests."

The present part is entitled "Barkbeetles of the Genus Dendroctonus," and deals with the more practical results of extensive investigations by Doctor Hopkins between 1891 and 1908, and of those conducted by him and under his immediate supervision by field and office assistants of this Bureau, Messrs. W. F. Fiske, H. E. Burke, and J. L. Webb. It relates to the most destructive enemies of the coniferous forests of North America, gives practical methods for their control, and serves as a supplement to Technical Series No. 17, Part I, the two publications together making a very complete technical and popular monograph of the genus Dendroctonus, the major part of which is based on original research. It is believed that these contributions will mark an important era in the history of forest entomology in America, and should be of special value to the systematic and economic entomologist and to students of forest entomology. This part should be of exceptional interest and value to practical foresters in the management of National and State forests, as well as to private owners of forests. The illustrations are mainly reproduced from Technical Series No. 17, Part I.

I recommend the publication of this manuscript as Bulletin No. 83, Part I, of the Bureau of Entomology.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE TO BULLETIN.

During the writer's investigations of extensive insect depredations in the forests of West Virginia, from 1890 to 1902, he was forcibly impressed with the importance of the forest-insect problem in connection with any future efforts toward the successful management of the forests of this country, and was thus led to give special attention to the subject. It was soon realized that among the principal groups of insect enemies of forest trees the scolytid bark and wood boring beetles must occupy first rank, both in economic importance and systematic interest. Subsequent investigations in West Virginia, in connection with the work of the West Virginia Agricultural Experiment Station, and in all of the principal forest regions of the country, in connection with the work of the Bureau of Entomology, have served to confirm these first impressions.

In these investigations special efforts have been made to acquire information on the habits and seasonal history and other facts relating to the various species, and to collect an abundance of material for systematic study, all to form a basis for conclusions in regard to the principal enemies of American forests and practical methods for their control.

The results of these investigations will be published in the two series of bulletins issued by the Bureau of Entomology. Those relating to the purely technical or systematic side of the subject, and of more direct interest to the systematic and economic entomologist and the general student of entomology, will be published in the technical series, while those of special interest to the economic entomologist, the student of forest entomology, the technical and practical forester, the owner of private forests, the manufacturer of forest products, and the public generally will be included in the regular, economic series of bulletins. The bulletins of each series are to be issued in parts, each part relating to a special group or genus as the work thereon is completed, thus avoiding the otherwise necessary delay in publication. A full index will be published to accompany each completed bulletin of several hundred pages.

A. D. H.

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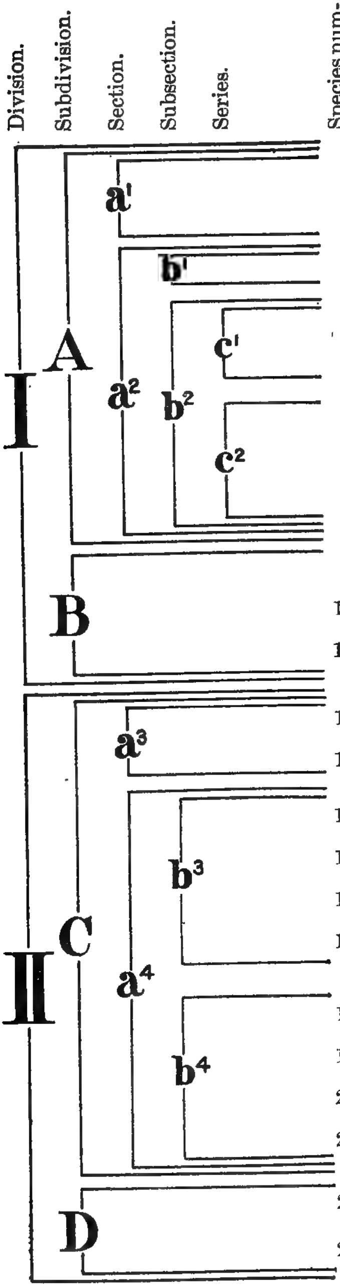

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7.	*parallelocollis* Chap.	7. Larger Mexican Pine Beetle.	74
8.	*approximatus* Dietz.	8. Colorado Pine Beetle.	76
9.	*monticolæ* Hopk.	9. Mountain Pine Beetle.	80
10.	*ponderosæ* Hopk.	10. Black Hills Beetle	90
11.	*jeffreyi* Hopk.	11. Jeffrey Pine Beetle	101
12.	*simplex* Lec.	12. Eastern Larch Beetle.	103
13.	*pseudotsugæ* Hopk.	13. Douglas Fir Beetle	106
14.	*piceaperda* Hopk.	14. Eastern Spruce Beetle.	114
15.	*engelmanni* Hopk.	15. Engelmann Spruce Beetle.	126
16.	*borealis* Hopk.	16. Alaska Spruce Beetle.	132
17.	*obesus* Mann.	17. Sitka Spruce Beetle	132
18.	*rufipennis* Kirby.	18. Redwinged Pine Beetle.	136
19.	*murrayanæ* Hopk.	19. Lodgepole Pine Beetle.	137
20.	*punctatus* Lec.	20. Allegheny Spruce Beetle.	139
21.	*micans* Kug.	21. European Spruce Beetle.	140
22.	*terebrans* Oliv.	22. Black Turpentine Beetle.	146
23.	*valens* Lec.	23. Red Turpentine Beetle.	153
24.	*adjunctus* Blandf.	24. Guatemala Beetle	

Position doubtful—

Classification of the Genus Dendroctonus, Showing Technical and Common Names and Species Numbers.

This diagram will enable the reader to refer at once to the technical and common names of any species number mentioned in the text, and will show at a glance the position and relations of the divisions, subdivisions, sections, subsections, series, and species into which the genus is divided.

U. S. D. A., B. E. Bul. 83, Part I. F. I. I., October 11, 1909.

PRACTICAL INFORMATION ON THE SCOLYTID BEETLES OF NORTH AMERICAN FORESTS.

I. BARKBEETLES OF THE GENUS DENDROCTONUS.

By A. D. Hopkins,
In Charge of Forest Insect Investigations.

INTRODUCTORY.

The first part of this bulletin supplements Technical Series No. 17, Part I, of this Bureau, in giving facts of practical interest and importance on a group of barkbeetles which contains the most destructive enemies of the principal coniferous forest trees of North America.

To avoid the too frequent repetition of technical and common names in the text or in footnotes, the species number is used, referring to the corresponding number in a classified list of technical and common names in Plate I.

The list of publications, in which references are to be found to some economic feature of one or more species, is arranged in chronologic instead of alphabetic order, so that the reference in the text is to the year in which the particular article referred to was published, as well as to the author's name. A more extensive bibliography is found in Technical Series No. 17, Part I.

HISTORICAL.

The name "Dendroctonus," which means *killers of trees*, was proposed in 1836 by Dr. W. F. Erichson to designate a genus of beetles which was then represented by two described species—the European spruce beetle (No. 21) (see Plate I) and the black turpentine beetle (No. 22). Between that time and 1897 ten more North American species, as at present recognized, were added, one (No. 18) by Kirby in 1837, one (No. 17) by Mannerheim, 1843, one (No. 23) by Le Conte, 1860, one (No. 4) by Zimmerman in 1868, two (Nos. 12 and 20) by Le Conte in 1868, one (No. 7) by Chapuis in 1869, one (No. 1) by Le Conte in 1876, one (No. 8) by Dietz, 1890, and one (No. 24) by Blandford in 1897. The writer has added twelve (Nos. 2, 3, 5, 6, 9, 10, 11, 13 to 16, and 19) North American species, but none has been added from any other part of the world. Therefore the genus is now represented by 23 species from North America and one from Europe.

The European species was early recognized as a destructive enemy of spruce and other coniferous trees, and much information has been published relating to its habits, life history, distribution, and methods of control.

Previous to the year 1891 only two species had been recognized in this country as depredators on forest trees. The black turpentine beetle had been referred to by Olivier, 1795, and the red turpentine beetle by Harris, 1826 to 1862, and by other writers, as enemies of pine, and the eastern spruce beetle (No. 14), under the name of another species (No 18), was recognized as a destructive enemy of the spruce in the northeastern United States and southeastern Canada and was the subject of special investigations and reports by several authors. In 1891 the writer found that the southern pine beetle (No. 4) was the cause of the death of pine and spruce timber over extensive areas in West Virginia and adjoining States, and it was the subject of special investigations and reports (Hopkins, 1892 to 1899). It was also mentioned in publications by Chittenden (1897), Schwarz (1898), and others.

In 1899 the writer made observations on the destructive habits of the western pine beetle (No. 1), the red turpentine beetle (No. 23), the mountain pine beetle (No. 9), and the Douglas fir beetle (No. 13), and observed the habits of the Sitka spruce beetle (No. 17). In 1900 the destructive work of the eastern spruce beetle (No. 14) in northwestern Maine was investigated, and in 1901 investigations were made on the Black Hills beetle (No. 10) and its depredations in the Black Hills of South Dakota were investigated.

Since July, 1902, many trips have been made by the writer to different sections of the country in general, and special investigations made of the work of one or more of the species of this genus, as noted further on, under "Basis of information," following the account of each species. Messrs. J. L. Webb, H. E. Burke, and W. F. Fiske, assistants in forest insect investigations, working according to the plans and under instructions of the writer, have given special attention to the study of the seasonal history, habits, etc., of the species found during their active field work.

Mr. Webb spent two seasons (1902 and 1906) in the Black Hills National Forest, principally in the study of the Black Hills beetle (No. 10) and its work and in conducting experiments with trap trees; one season (1904) in the San Francisco National Forest, giving special attention to species 2, 3, and 8, and one season (1905) in central Idaho, studying the western pine beetle (No. 1) and in conducting experiments with trap trees. He also spent the season of 1906 in the Black Hills to complete the investigations on the Black Hills beetle and the season of 1907 in the national forests of southern New Mexico and Arizona in general field work.

Mr. Burke spent three seasons (1903, 1904, and 1905) in western and northwestern Washington in general forest insect investigations, and made observations on the Sitka spruce beetle (No. 17) and the Douglas fir beetle (No. 13). He also made special trips to Idaho and South Dakota in 1904 to determine certain facts relating to the western pine beetle (No. 1) in Idaho and the Black Hills beetle (No. 10) in South Dakota. In 1906 he spent the greater part of the season in the Yosemite National Park, under instructions to make special studies of the mountain pine beetle (No. 9), the western pine beetle (No. 1), and the red turpentine beetle (No. 23), and in 1907 he made observations on the southwestern pine beetle (No. 2), the Black Hills beetle (No. 10), and other species in the forests of Utah.

Mr. Fiske gave special attention to the investigation of the southern pine beetle (No. 4) and its work, experiments with trap trees, etc., during his general investigations of forest insects in the South Atlantic and Gulf States during the seasons of 1903, 1904, 1905, and 1906, and studied the seasonal history and habits of the black turpentine beetle (No. 22) and the red turpentine beetle (No. 23)—the latter in the mountains of North Carolina. In the fall of 1906 he made observations on the eastern larch beetle (No. 12) and the redwinged pine beetle (No. 18) in northwestern Michigan, and in the spring of 1907 he made observations on species 4 and 22 in Texas and on species 2, 3, 5, 8, 13, 15, and 23 in southern New Mexico.

This field work by the writer and his assistants has resulted in the accumulation of a mass of material in specimens and notes which has served as a basis for the preparation of this part of the bulletin.

Considerable material has also been received from officials of the Forest Service, together with information in regard to the location and extent of depredations, and from owners of private forests and other correspondents in different sections of the country who have notified us of troubles affecting the timber and have responded to our requests for specimens and detailed information in regard to the character and extent of the depredations.

DESTRUCTION CAUSED BY THE BEETLES.

The results of our investigations have clearly shown that some of the species of this genus of beetles are the most destructive enemies of the coniferous forest trees of North America. As examples, we have only to cite the well-known depredations by the eastern spruce beetle (No. 14) in the northeastern United States and New Brunswick during the past century (Hopkins, 1901*a*), the widespread destruction of pine and spruce by the southern pine beetle (No. 4) in West Virginia and Virginia in 1891 and 1892 (Hopkins, 1899*a*), the destruction of a large percentage of the timber in an entire National Forest by the Black Hills beetle (No. 10) within the past ten years (Hopkins, 1902*b* and 1905), and the depredations by the western pine beetle (No. 1) in Idaho, Oregon, and California (Webb, 1906), and by the mountain pine beetle (No. 9) in Wyoming, Montana, Idaho, Oregon, Utah, and California noted in the present paper.

CHARACTER AND EXTENT OF DEPREDATIONS.

Living healthy trees are attacked by swarms of the adult beetles, which enter the bark on the main trunk and excavate their egg galleries for a distance of a foot or more through the inner, living bark. This weakens the vitality of the tree, and in addition the larvæ hatching from the eggs mine through and destroy the bark intervening between the egg galleries, thus completely girdling the trees and causing their death. The amount of timber killed in this manner during the past century has been enormous. That known to have been killed by these beetles in West Virginia, New England, and the Black Hills National Forest alone amounts to many billions of feet of the best pine and spruce, to say nothing of the less conspicuous depredations each year scattered through the forested sections of the Rocky Mountain, Cascade, Sierra, and Coast regions, and of the Southern States. Very conclusive evidence has also been found that some of the great denuded areas in the Rocky Mountains region supposed to have been caused by forest fires were primarily caused by one or more species of Dendroctonus. From our present knowledge of the facts and evidence it is probable that if the timber destroyed by these insects in the United States during the past fifty years were living to-day its stumpage value would be more than $1,000,000,000.

POSSIBILITIES OF CONTROL.

The results of our investigations, experiments, and practical demonstrations make it clear that wherever private forests or State or National forests are under organized management for fire protection and economic utilization the control of these insects is often a less difficult and less expensive problem than that of controlling forest fires. In fact, wherever there is a sufficient demand for the timber, and where facilities for the utilization of the trunks of the infested trees within a specified time exist, the desired control may often be brought about and maintained practically without cost or even at a profit, especially if the action be taken before the depredators have spread over extensive areas.

If, when first discovered, the depredations of the beetles have already involved an extensive area, or if they are neglected until a large percentage of the timber is killed, their artificial control will be as difficult and expensive as that of a neglected forest fire. Furthermore, if the depredations occur in an inaccessible section of the forest or where the conditions as to labor and other facilities are unfavorable for necessary action, nothing more can be done toward the control of the beetles than under the same conditions in controlling a fire. But with the rapid extension of modern forest management, lumbering operations, and working plans into the principal public and private forests, and especially with the adoption of fire-control regulations under an organization of fire patrols and rangers, there will be no excuse for neglecting the insects.

THE BEETLE PROBLEM AS IMPORTANT AS THE FIRE PROBLEM.

In certain sections of the country and in certain National Forests where the more destructive species of beetles are present and a constant menace to the standing timber, the beetle problem is undoubtedly as important as the forest-fire problem, and therefore demands the adoption and organization of beetle-control work, which, with little or no additional force and equipment, can be conducted by fire patrols and forest rangers.

The evidence of destructive beetle work is not quite as distinct as is the evidence of fire, and can not be seen quite so far, but a clump of yellow-top or red-top trees can be seen for a long distance, and upon closer inspection the pitch tubes and boring dust on and around the trunks of living trees are sufficient danger signals to demand that the required action be taken to prevent widespread depredations.

There is one great advantage in the requirements for successful beetle control over those for fire control, viz, there is usually a period of six to ten months in which to utilize or otherwise dispose of the affected timber to destroy the broods of beetles in the bark, while a fire requires immediate attention.

DISTINCTIVE CHARACTERS OF THE GENUS.[a]

The beetles of the genus Dendroctonus (see figs. 1, 2, 3, etc.) are distinguished in the adult stage by their cylindrical, somewhat elongate to stout bodies, broad and prominent heads, nearly round to oblong-oval and transversely placed eyes behind the base of each antenna, the last with an elongate, clublike basal joint (scape) followed by 5 short joints (funicle) and terminated by a broad club which is thickened at the base and flattened toward the apex, and

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[a] See also Technical Series No. 17, Part I, for technical descriptions of genus, species, etc.

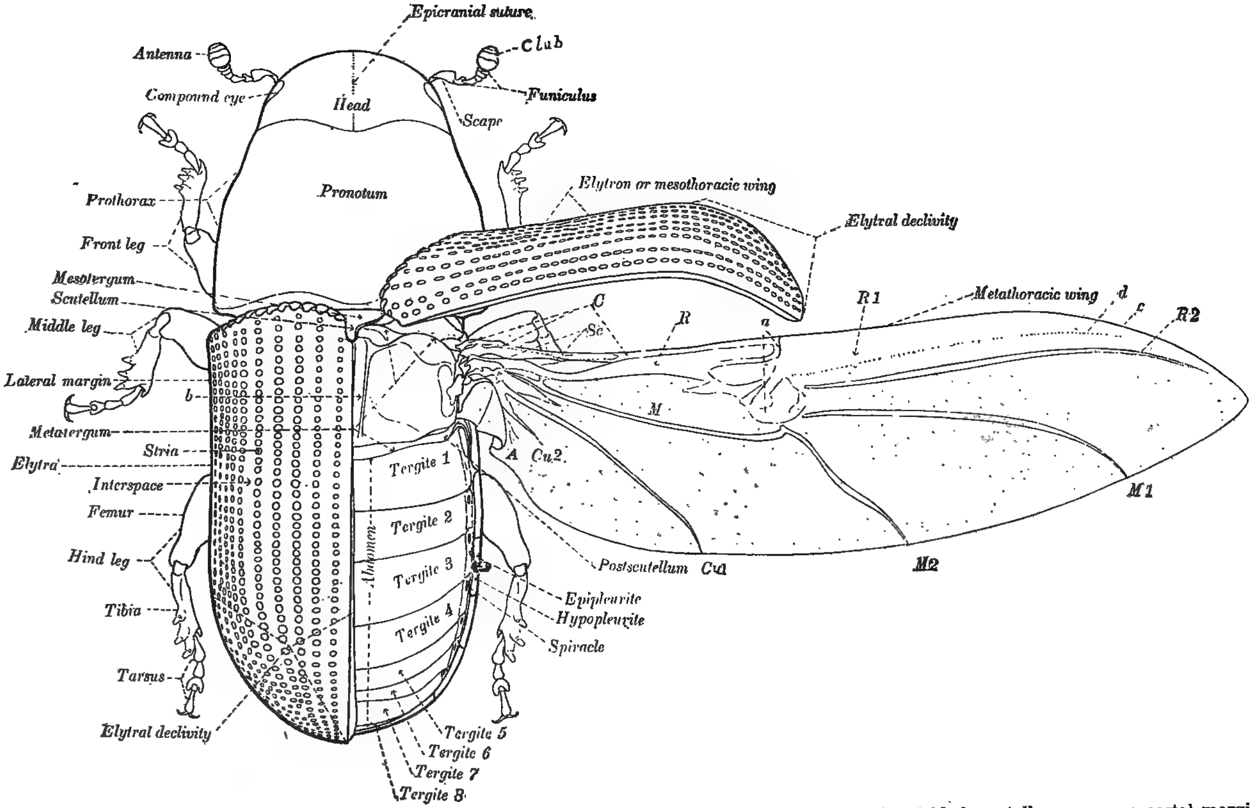


FIG. 1.—The red turpentine beetle (*Dendroctonus valens*). Adult, dorsal aspect, greatly enlarged: *a*, Median fold; *b*, scutellar groove; *c*, costal margin; *d*, inter-radial fold; *Sc*, subcosta; *R*, radius; *R1*, radius 1; *R2*, radius 2; *C*, costa; *M*, media; *M1*, media 1; *M2*, media 2; *Cu1*, cubitus 1; *Cu2*, cubitus 2; *A*, anal. (Author's illustration.)

has three to four closely connected joints defined by curved lines. The front of the head has a distinct middle elevation toward the base of the mandibles, called the epistomal process (see figs. 2, 3). The pronotum is slightly more than half to slightly less than half as long as the elytra, which have fine to coarse rugosities between rows of obscure to distinct punctures.

The diagram, Plate I, gives the technical and common names of the beetles of the genus, and shows how the different species fall into natural primary and minor divisions according to certain structural characters and peculiar habits.

ADULT CHARACTERS.

In the species of Division I the pronotum is somewhat elongate and as broad as the elytra, and in those of Division II the pronotum is shorter and is usually narrower than the elytra.

In species 1 to 8 (subdivision A) the body is somewhat slender, and the pronotum is but slightly narrowed toward the head, which in all but species 3 (comprising subsection b^1) has a frontal groove and two frontal elevations. In species 1 and 2 (section a^1) the elytra are without long hairs, while in species 3 to 8 (section a^2) there are long hairs toward and on the declivity.

In species 9 to 11 (subdivision B) the body is stouter and the pronotum is distinctly narrowed toward the head, which is without frontal groove or elevations. In species 9 and 10 the punctures of the pronotum are moderately coarse and deep, while in species 11 they are shallow and usually fine, with the surface more shining.

In species 12 to 21 (subdivision C) the punctures of the pronotum are of irregular size, while in species 22 and 23 (subdivision D) they are regular.

In species 12 and 13 (section a^3) the striæ of the elytral declivity are deeply impressed, and the interspaces are convex, while in species 14 to 21 (section a^4) the striæ are but slightly or not at all impressed and the interspaces are flat or but slightly convex. In species 14 to 19 the striæ of the elytral declivity have obscure to fine punctures, while in species 20 and 21 the strial punctures are coarse and distinct. Species 22 and 23 are easily distinguished by their large size, evenly punctured pronotum, which is subelongate and almost as broad as the elytra, and by the very large and prominent head.

EXTERNAL SEXUAL CHARACTERS.

In species 1 to 8 (subdivision A) the females are distinguished by a transverse, rather broad, elevated ridge across the pronotum near the anterior margin, moderately broad head, and moderately large mandibles. The males are without the transverse ridge across the

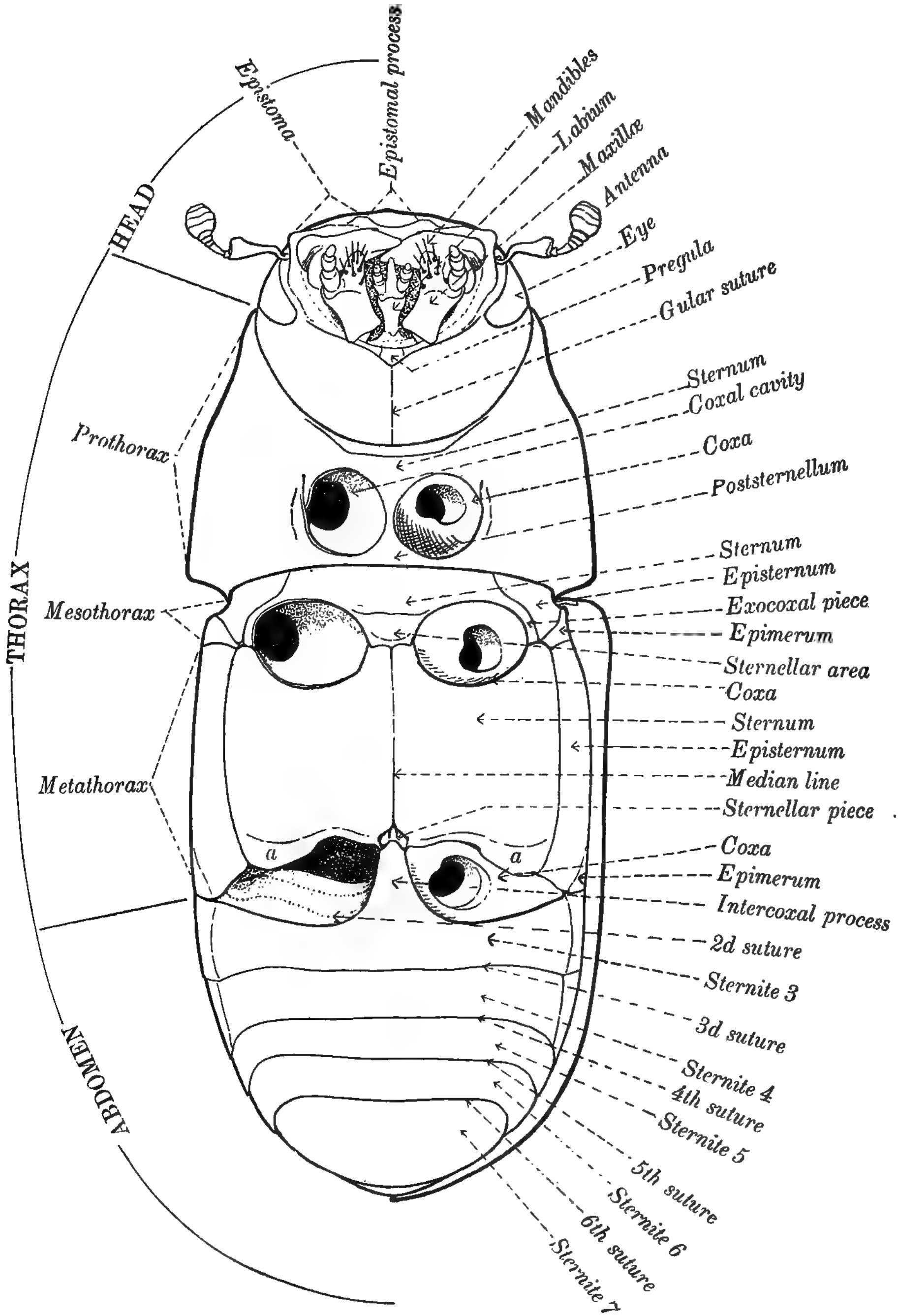


FIG. 2.—The red turpentine beetle. Adult, ventral aspect, greatly enlarged: *a*, Sternellar area. (Author's illustration.)

pronotum; but the frontal groove and tubercles are usually more distinct, the head broader, and the mandibles stouter.

In species 9 to 11 (subdivision B) the females have the declivity of the elytra somewhat flattened and shining and the interspaces with

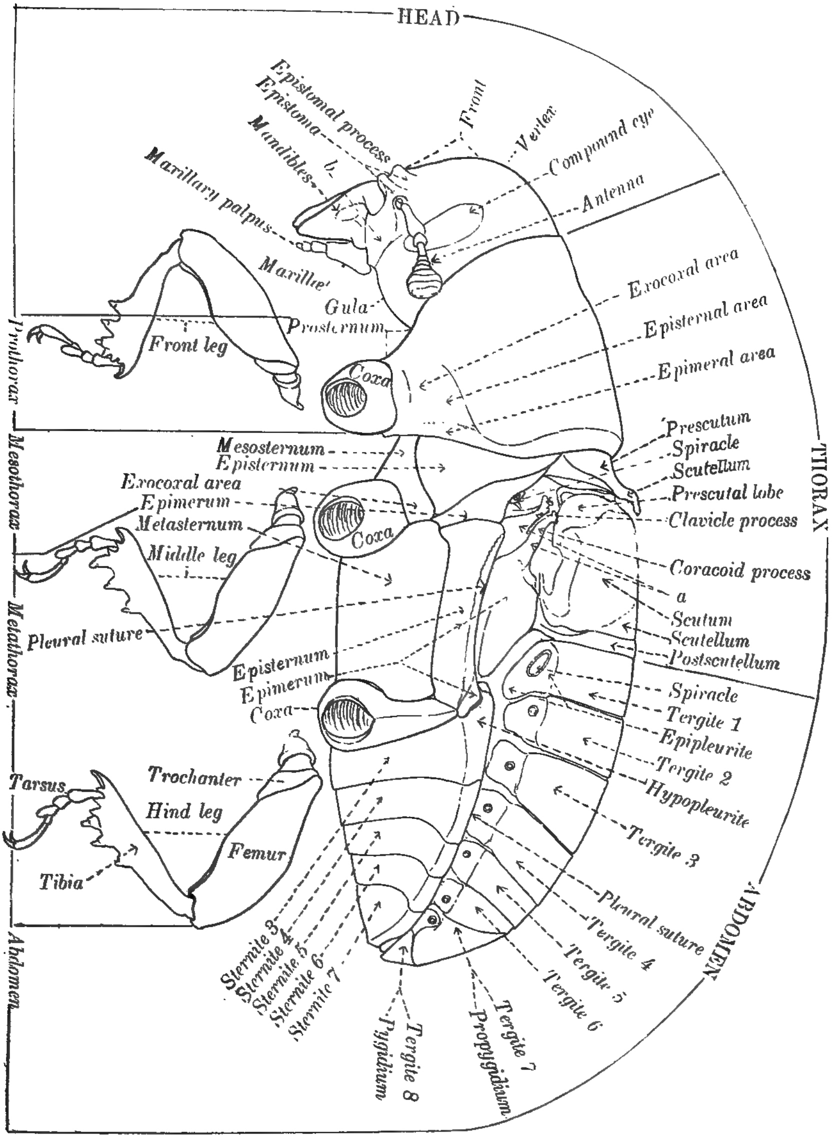


FIG. 3.—The red turpentine beetle. Adult, lateral aspect, greatly enlarged: *a*, Pleural clavicula; *b*, pregena. (Author's illustration.)

small granules and sometimes punctured. In the males the declivity is more convex, the interspaces have coarser granules, the head is broader, and the mandibles are stouter.

In species 12 to 21 (subdivision C) the sexes are easily distinguished by the differences in the declivity of the elytra. In the females the striæ are more distinctly impressed and the interspaces more convex and roughened. In the males the striæ are much less or not at all impressed and the interspaces are shining, smooth, and often punctured.

In species 12 and 13 (section a^3) the striæ are deeply impressed in both sexes; but in species 14 to 21 (section a^4) they are rarely impressed in the males.

In species 22 and 23 (subdivision D) the sexes are less distinctly defined by external characters. In the females the antennal club is broader, stouter, and more compressed; the head is narrower and the mandibles are smaller, while the reverse is true in the males.

THE EGG.

The eggs of the majority of the species have been observed and apparently show no differences except in relative size, corresponding with the size of the adults. They are slightly oblong, rounded at the ends, pearly white, and shining.

THE LARVA.

The larva (fig. 4) is a stout, cylindrical, yellowish-white, footless grub with a yellowish shining head. The body is deeply and closely wrinkled, as shown in the figure.

In species 1 to 11 the dorsal surface of the 8th and 9th abdominal segments are smooth, without chitinous plates, and the ventral prothoracic lobes are more or less prominent.

In species 1 and 2 the front is without a median elevation.

In species 3 to 7 the front has a more or less rounded convex elevation.

In species 9 to 11 the front has a transverse roughened elevation, slightly more elevated toward the sides.

In species 12 and 13 the dorsal surface of the 8th and 9th abdominal segments is without chitinous plates.

In species 14 to 23 one or both have distinct plates.

In species 14, 15, 17, and 19 the 8th and 9th abdominal plates are without prominent spines. The frontal elevation, when present, is transverse.

The larvæ of species 16 to 18 and 19 have not been observed.

Species 21 has a roughened plate on the 9th segment, but none on the 8th.

In species 12 the front is without a median elevation, but in species 13 there is a distinct transverse, rugose, median elevation, more elevated toward the sides.

In species 14, 15, and 19 the front has a transverse elevation, but in 17 it is absent or indistinct.

In species 22 and 23 the dorsal plates of the 8th and 9th segments have prominent spines, and the front of the head is without elevations.

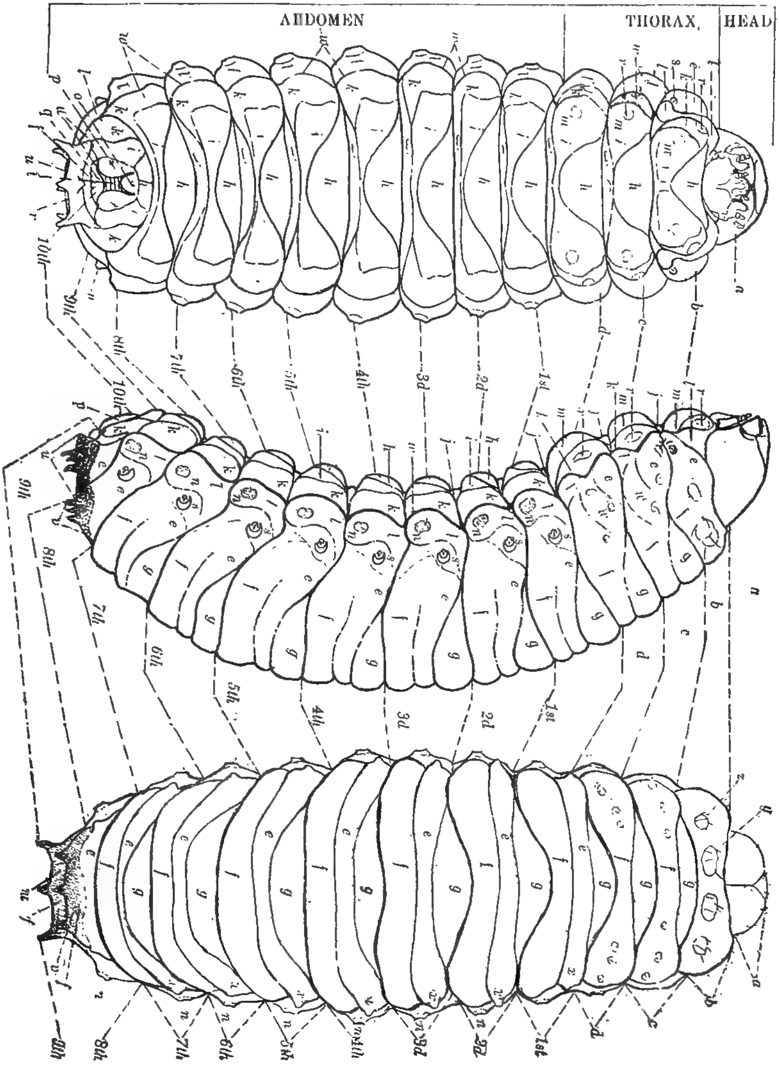


FIG. 4.—The red turpentine beetle. Larva, ventral, lateral, and dorsal aspects, greatly enlarged: *a*, Head; *b*, prothoracic segment; *c*, mesothoracic segment; *d*, metathoracic segment. Lobes: *e*, Scutal; *f*, scutellar; *g*, prescutal; *h*, sternal; *i*, sternellar; *j*, poststernellar; *k*, hypopleural; *l*, epipleural. *m*, *m*, Foot calli; *n*, *n*, epipleural calli and tubercles; *o*, infraanal lobe or sternite of the 10th segment; *p*, paranal lobe or 10th pleurite; *q*, supraanal lobe or tergite of the 10th segment; *r*, hypopleural callus; *s*, spiracle; *t*, anal opening; *u*, dorsal plate of 9th segment with scutellar spines; *v*, dorsal plate of 8th segment with scutellar spines; *w*, pleural suture; *x*, spiracular tubercles; *y*, prothoracic dorsal plate; *z*, prothoracic lateral plate. (Author's ill.)

THE PUPA.

The pupa (fig. 5) is of the general color of the larva, but is of the general form and size of the adult, with the legs and wing pads folded beneath the body and the abdominal segments exposed. The 9th segment has two prominent fleshy spines, and the other segments are with or without dorsal, lateral, and pleural spines, which vary in size among the different species from very smooth to quite coarse and prominent.

In species 1 to 5 and 8 to 11 the vertex or front of the head is grooved, with prominent or small fleshy spines situated at each side of the groove.

The pupæ of species 6 and 7 have not been observed.

In species 1 to 5 and species 8 the elytral pads are smooth and the abdominal segments have small lateral spines or tubercles.

In species 1 and 2 the vertex of the head is faintly grooved, the spines are small and widely separated, and the front and middle femora are without apical spines or granules.

In species 3 the vertex is faintly grooved, the spines are very small, and the front and middle femora have apical granules.

In species 4, 5, and 8 the vertex is broadly grooved, the spines are moderately small and widely separated, and the front and middle femora have small apical tubercles.

In species 9, 10, and 11 the elytral pads are roughened, with sparsely placed granules. The head has the vertex deeply grooved and the spines prominent, and the abdominal segments have very long lateral spines. In species 9 and 11 the front and middle femora have two apical spines each, while in species 10 they have one each.

In species 12 to 23 the vertex is either faintly impressed or convex, with an acute granule at each side and one or two on each side on the front. The elytral pads are smooth, and the abdomen has more or less prominent lateral spines.

In species 12 and 13 the vertex of the head is faintly impressed or grooved, and the front and middle femora are without granules or spines.

In species 14 to 23, so far as observed, the vertex is convex, and the femora have small apical granules.

EGG GALLERIES, LARVAL MINES, AND PUPAL CELLS.

(See figures of work.)

In species 1 to 11 the egg galleries are winding to straight, with individual larval mines concealed or exposed in inner bark and with the pupal cells either in the outer or in the inner bark.

In species 1 to 8 the egg galleries are winding, nearly transverse to oblique; the larval mines short, not in groups; and the pupal cells are in the outer bark. In species 1, 2, 5, 6, 7, and 8 the larval mines are concealed, while in species 3 and 4 they are exposed in the inner bark.

In species 9 to 11 the egg galleries are longitudinal, slightly winding to straight. The larval mines are short and usually in groups, and both the pupal cells and larval mines are exposed in the inner bark.

In species 12 to 23, so far as observed, the egg galleries are longitudinal, straight to slightly winding, with the larval mines either in groups or connected, or they form a broad common chamber, and all are exposed in the inner bark. The pupal cells are located at the end of the larval mines or in the larval chambers and are usually exposed.

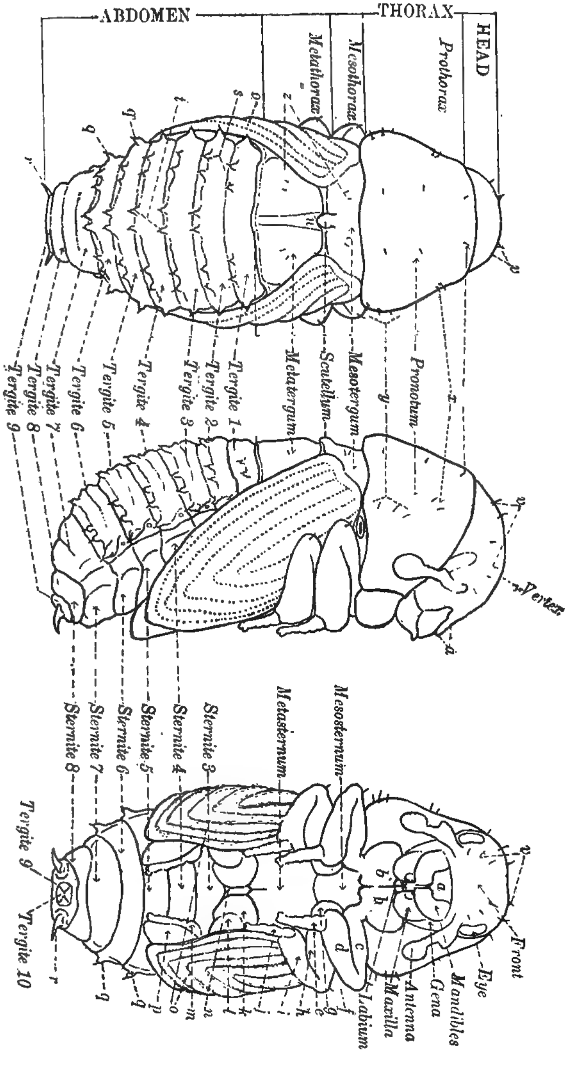


FIG. 5.—The red turpentine beetle. Pupa, dorsal, lateral, and ventral aspects, greatly enlarged: *a*, Epistomal bristle-pad or pseudo-labrum. Anterior leg: *b*, *b*, Coxæ; *c*, femur; *d*, tibia; *e*, tarsus; *f*, apical spines of femur. Middle leg: *g*, Coxa; *h*, femur; *i*, tibia; *j*, tarsus. Posterior leg: *k*, Coxa; *l*, femur; *m*, tarsus. *n*, Sterneller or intercoxal area; *o*, elytral pad; *p*, wing-pad; *q*, pleural spines; *r*, caudal spine or 9th pleural; *s*, lateral spines; *t*, dorsal spines; *u*, scutellar groove; *v*, frontal spines; *w*, dorsal spines of pronotum; *x*, lateral spines of pronotum; *y*, pleural spines of pronotum; *z*, mesotergal and metatergal spines. (Author's illustration.)

In species 12 to 13 the egg galleries are straight or slightly winding, sometimes branched, the larval mines are in groups and exposed in the inner bark, and the pupal cells are exposed or concealed.

In species 12 and 13 the egg galleries are long, longitudinal, straight, or slightly winding, sometimes branched, and moderately broad; the larval mines are long, independent of each other from the start, winding, and more or less regular.

In species 14 to 21, so far as observed, the egg galleries are broad, moderately long, straight, irregularly branched at terminals, and usually with an inner gallery through the packed borings of the finished egg galleries; the larval mines are long, connected toward the egg gallery, independent and irregular, or forming a broad larval chamber.

In species 14, 15, and 17 the larval mines are connected toward the egg gallery and separated toward the middle and outer ends.

In species 19 and 20 the larvæ excavate a common or social chamber, sometimes with independent mines extending from the edges.

In species 22 and 23 the egg galleries are broad to very broad, short to very long, and straight or slightly winding, and the larval mines form very large common chambers, with the pupal cells in the chamber or at the ends of short independent mines extending from the edge of the chamber.

DISTRIBUTION.

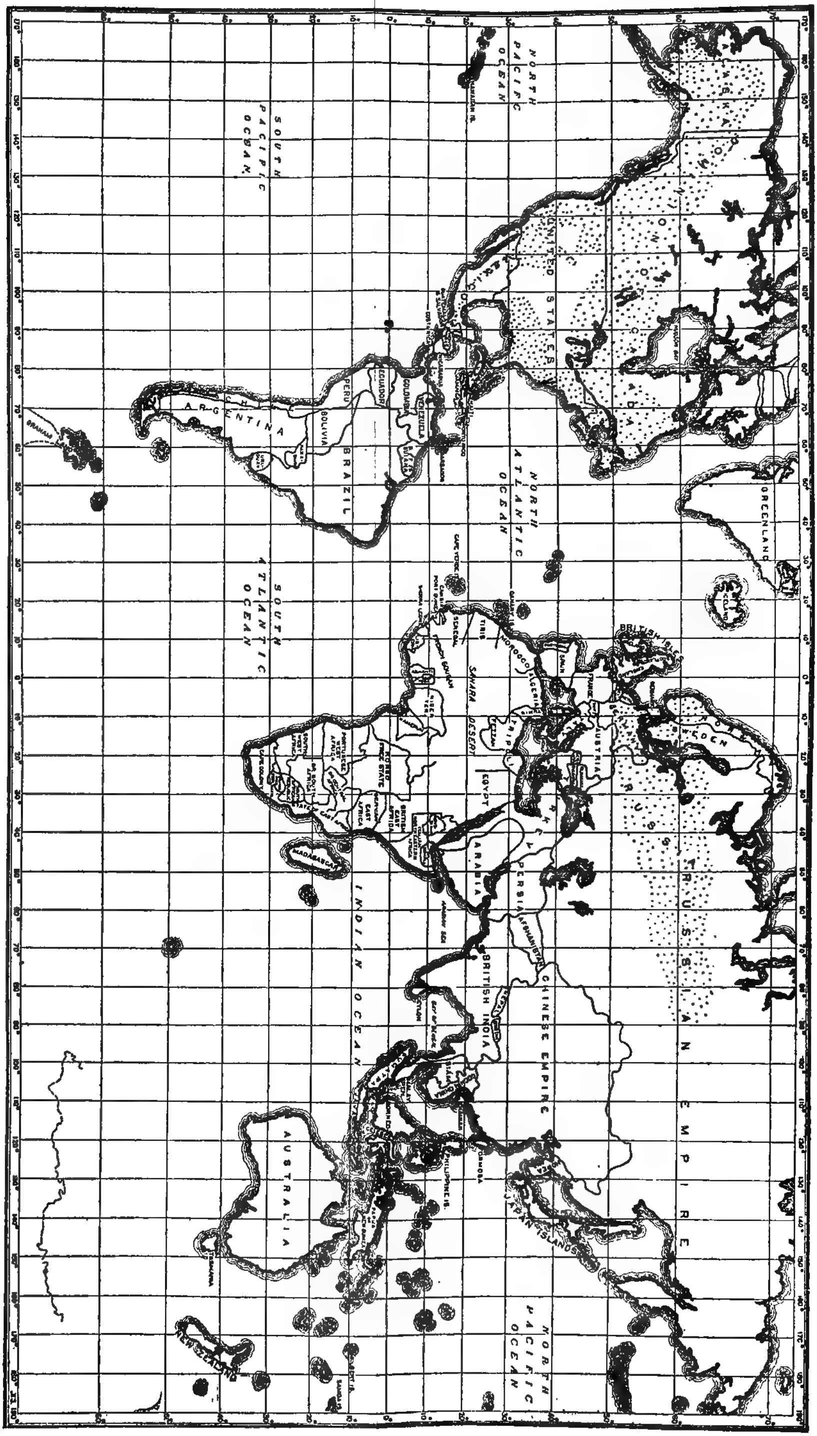
The distribution of the species of Division I is from the South Atlantic States to Mexico and Central America, and northward into the Rocky, Sierra Nevada, and Cascade mountains to British Columbia.

Species 1 occupies the region of the western yellow pine west of western Montana and southern Idaho, southward to Santa Barbara County, Cal., while species 2 occupies the Rocky Mountains region south of central Colorado and central Utah, into southern California and northern Mexico.

Species 3, 5, and 8 occupy practically the same region as species 2, while species 4 occupies the region of yellow pine, loblolly pine, and longleaf pine south of Pennsylvania and westward into Texas, and species 6 and 7 occupy the pine regions of the mountains of southern Mexico.

Species 9 occupies the region of silver pine, lodgepole pine, and sugar pine north of Colorado and Utah and westward into the Sierra Nevada and Cascade mountains.

Species 10 occupies the region of the Rocky Mountain variety of the western yellow pine and limber pine above an altitude of 6,000 feet, from western South Dakota southward through Wyoming, Colorado, and Utah to southern New Mexico and Arizona, while species 11 occupies the Jeffrey-pine region from the mountains of San Bernardino County, Cal., to northern California, and probably into Oregon.



MAP OF THE WORLD, SHOWING DISTRIBUTION OF THE GENUS DENDROCTONUS. (AUTHOR'S ILLUSTRATION.)

The species of Division II range from Guatemala northward to Alaska, eastward to the Atlantic coast, and across northern Europe and Russia into Siberia.

Species 12 occupies the regions and sections of eastern larch from northwestern West Virginia, northward and westward, while species 13 occupies the region of the Douglas fir, bigcone fir, and western larch from southern New Mexico and Arizona to Ventura County, Cal., and northward into British Columbia.

Species 14 occupies the region of red spruce from the high mountains of Pennsylvania northward and from New Brunswick to northwestern Michigan, and probably northwestward to the 100th meridian.

Species 15 occupies the region of Engelmann spruce from the white spruce in western South Dakota westward, and north of southern New Mexico.

Species 16 occupies the white-spruce region in Alaska, and species 17 the Sitka-spruce region from southern Oregon to Sitka.

Species 18 occupies the Lake Superior region; species 19 the region of lodgepole pine from central Colorado northward probably into British Columbia; species 20 the regions of red spruce from the mountains of West Virginia into New York; while species 21 occupies the spruce and pine regions north of central Europe in Denmark and through Russia to eastern Siberia.

Species 22 occupies the region of pitch pine, Virginia pine, yellow pine, loblolly pine, and longleaf pine from Long Island, New York, east of the Allegheny Mountains, southward to Florida and Texas, and west of the mountains from the Little Kanawha River probably through Kentucky and Tennessee, while species 23 occupies the regions of pine timber from the Atlantic to the Pacific north of the South Atlantic and Gulf States and south into the mountains of Guatemala. Species 24 is described from Guatemala.

The distribution maps (figs. 11, 14, 17, etc.) show the known and probable ranges of each species, the known range being indicated by large dots and the probable range by small dots.

The distribution of the genus is shown on a map of the world (Pl. II.)

HOST TREES.

In Division I the species confine their attack to pine and spruce, but principally to the pines.

Species 1 confines its attack to the western yellow and sugar pine, and is a destructive enemy of both. Species 2 attacks the western yellow pine, but, so far as observed, is much less destructive than its northern and western neighbor. It has also been found in the Douglas fir, but this is evidently an abnormal habit.

Species 3, 5, and 8 are usually associated with No. 2 in the western yellow pine, but none of them has been especially destructive, although independently or collectively they are capable of being so. Species 4 attacks all of the pines and spruces within its range, and while it caused widespread devastation in its northern range during 1891 and 1892 its destruction of timber within its southern range, so far as observed, is comparatively moderate.

The species of subdivision B are the most destructive insect enemies of western pine forests. Species 9 attacks the western white pine, silver pine, sugar pine, lodgepole pine, and western yellow pine, and is exceedingly destructive in certain localities throughout its range, especially to the silver pine, sugar pine, and lodgepole pine. Species 10 attacks the Rocky Mountain variety of the western yellow pine, limber pine, white spruce, and Engelmann spruce, but confines itself principally to the yellow pine and is exceedingly destructive, as has been conclusively demonstrated in the Black Hills Forest Reserve of South Dakota and in numerous localities in Colorado. Species 11 attacks the Jeffrey pine and western yellow pine, but principally the former, to which it is quite destructive.

The species of Division II attack pines, spruces, larches, and Douglas fir, and some of the species are very destructive to living timber.

Species 12 confines its attack to the eastern larch. There is no positive evidence that it is primarily destructive to living timber, but it evidently contributes to the death of trees defoliated by the larch worm. Species 13 confines its attack principally to the Douglas fir, but is also found in the bigcone spruce and western larch. In the northwestern section of its range this species is not especially destructive, but in its eastern and southern range it is very destructive to the Douglas fir.

Species 14 attacks the red spruce, black spruce, and white spruce, and from time to time during the past century it has been exceedingly destructive to the red spruce in Maine and New Brunswick. Species 15 attacks the Engelmann and evidently the other spruces of the Rocky Mountain region. There is conclusive evidence that it has caused widespread devastation of matured spruce during the past fifty years, and it is now quite aggressive in some localities. Species 16 has been found in the white spruce, but nothing more is known of its habits. Species 17 attacks the Sitka spruce, but there are no records to indicate that it has been primarily destructive to living timber. Species 18 lives in the white pine, but nothing further is known of its habits. Species 19 attacks living lodgepole pine and Engelmann spruce, but it is not known whether or not it is primarily destructive. Species 20 was found in the living bark on a red-spruce stump in West Virginia, which is all that is known of its habits.

Species 21 is recorded as attacking spruce and pine principally, and as sometimes attacking larch, and fir (Abies), and is recognized as a destructive enemy.

Species 22 attacks the different species of pine within its range and has also been found in spruce. It is sometimes destructive to living trees, but more often is simply injurious to the base of the trunks in causing basal scars. Species 23 attacks all of the pines and is sometimes found in spruce and larch. It rarely causes the death of trees but causes serious damage to the base of living trees, resulting in the common defect known as basal scars and fire wounds.

EVIDENCES OF ATTACK.

In all of the species the first evidence of attack on living trees is the presence of pitch tubes on the trunks, mixed with reddish borings, or the presence of reddish boring dust in the loose bark and around the base of the trees. Later the fading, yellowish, or reddish condition of the foliage is conspicuous evidence of the barkbeetles' destructive work.

Successful attacks by species 1 to 8 are followed by a rapid death of the trees. The leaves fade in a month or two and turn yellow and reddish before winter. Successful attacks by species 9 to 11 are followed by a slow death of the trees. While the trees attacked during the summer will have the bark on the trunks killed, the leaves will not turn yellow until the following May.

Attacks by species 12 and 13 are not as a rule indicated by pitch tubes, but the reddish boring dust in the crevices of the bark, in the loose bark, and around the base of the trunk of Douglas fir or larch is quite conclusive evidence of their presence. Douglas fir attacked in the summer will have the leaves fading and turning pinkish in the fall and winter, and reddish in the spring. The leaves on the larch probably fall before they fade, although some of them may remain on the trees after the normal time for them to fall.

In species 14 and 15, pitch tubes and red boring dust, mixed with resin, on the trunk and around the base, are evidences of attack. The trees attacked in the early summer will shed their green needles before fall. Those attacked later in the summer will have the bark on the trunks killed before winter, but the leaves may remain green until growth starts in the spring, when they will fall. Thus in May and June one often finds the ground beneath the infested trees covered with the green needles. After the leaves have fallen the bare twigs will cause the tops of infested trees to present a reddish appearance.

Species 18 to 20 appear to confine their attack to or toward the base of the trees, where large pitch or gum tubes are formed, indicating their presence. In Europe, species 21 sometimes attacks the trunk at points some distance above the base, where the large pitch or gum tubes indicate their presence.

Species 22 and 23 nearly always attack the base of the trees, where the very large pitch tubes and masses of pitch indicate their work. When the main trunk is infested by these species to a sufficient extent to kill the trees, the evidence of infestation is found in the large pitch tubes and yellow foliage of the dying trees.

SEASONAL HISTORY.

The important features in the seasonal history of these beetles are the hibernation or overwintering of the broods, the beginning of activity in the spring, the emergence and flight of the adults, the beginning and ending of the period of principal attack, the period of larval development, the principal period of transformation from the larvæ to the pupæ and adults, the beginning and ending of the period of emergence, and the number of generations annually.

Certain features in the seasonal history of all of the species are similar, but as a rule each species or series of closely related ones has peculiarities which are more or less distinctive. A knowledge of these facts, therefore, is of prime importance as a basis for advice relating to the exact species involved in a given trouble and the successful methods of control.

The broods of all of the species pass the winter as adults and larvæ in the bark of the trees, logs, or stumps attacked during the preceding spring, summer, or fall. All excavate galleries through the inner living bark in which to deposit eggs, and the larvæ of all feed on the inner bark; all become more or less active as soon as the weather conditions are favorable in the spring, especially the larvæ and overwintered parent adults, the former extending their larval mines and the latter their egg galleries. The principal differences in seasonal history are brought out in the following references to the general features of the different species and in the detailed discussion under each species farther on.

In species 1 and 2, under average conditions, there is one complete generation and a partial second during the season of activity.

In species 1 the first attack is made during the last week in June and first week in July, and the more advanced broods develop and begin to emerge about the last of August, but are not all out before cold weather. The first eggs of the second generation are deposited about the first of September, but the broods do not develop beyond the larval stage before hibernation begins in October. In species 2 the seasonal history is practically the same as in species 1, except that the attack and subsequent stages begin a month earlier. The attack begins during the last of May, and the advanced broods begin to emerge during the latter part of July.

In species 3 there is but one generation annually in the more advanced broods, while the more retarded ones may pass through two winters before they complete their development and emerge. The adults begin to emerge, attack other trees, and deposit eggs toward the last of June, but the broods do not develop before hibernation begins in the fall.

Species 4 has two or three generations annually in its northern range. In the intermediate range, represented by Tryon, N. C., there are three or four generations, while in the more southern range there may possibly be five generations, with activity continuing during the warmer days of winter. Under average conditions the first attack is made about the middle of May, and under favorable conditions the resulting brood develops to adults and emerges in about sixty days.

Species 5 evidently has a seasonal history similar to species 2

In species 8 there is but one generation annually. The attack begins in June, and the broods do not emerge until the following June to August, or later.

In species 9, 10, and 11 there is but one generation annually, and the seasonal history of each is quite similar to that of the others. The first attack is made during the last week in July or first week in August, and the broods do not develop and emerge until the following July and August.

In species 12 and 13 there is a single generation annually. The first attack is made in April to May, and the broods emerge the following April to July.

In species 14 and 15 there is but one generation annually. The first attack is made in June, and the broods do not emerge until the following June to August. In species 17 the attack begins a month earlier. In the European species (No. 21) the first attack is made in May and June, and the broods emerge the following May to August.

In species 22 and 23 there is but one generation annually. The attack is made during the first warm days in March to April, and the broods emerge the following March to September, or later.

INFLUENCES OF LATITUDE AND ALTITUDE ON SEASONAL HISTORY.

The beginning and ending of the hibernating period vary somewhat among the different species, and in each species there is considerable difference at different latitudes and altitudes within its range. Within the area of a given State or section of the country this difference in the beginning or ending of a given period in the seasonal history of a species can be estimated after the date of beginning is determined for a given season in a given locality. In the spring of a given year the average difference in the time of beginning activity, emergence, flight, attack, etc., at the same altitude, will not vary much from four days later for each degree north, or four days earlier for each degree south, while at the same latitude there will be a difference of about four days for each 400 feet difference in altitude—four days later for each 400 feet higher, and four days earlier for each 400 feet lower. Thus a difference of 7½ degrees of latitude at the same elevation would mean a difference of about thirty days in the beginning of activity or any other event, depending on a given average temperature, while a difference of 3,000 feet in altitude at the same degree of latitude would cause an equal difference in these phenological events.

In the fall of the year the beginning of hibernation and other events will be earlier northward and later southward at localities of the same elevation, or earlier at higher altitudes and later at lower altitudes in the same latitude.

Of course there are exceptions to these rules, especially in regions like that of California, where remarkably abnormal conditions as to influence of altitude and latitude prevail, as also in the case of southern and northern exposures, sandy dry soils, and wet clayey soils or bogs. In such cases the estimates must be corrected so as to allow for three or four days later for the beginning of activity, etc., under average colder conditions, or three or four days earlier for average warmer conditions. The best indication of the rate of difference between two localities is found in the average difference in the dates of opening of the buds or flowers of some indigenous species of forest trees common to both localities, and especially of a species of conifer subject to the attack of a given Dendroctonus beetle.

A knowledge of the facts relating to this principle is of especial importance as a basis for recommending or executing beetle-control policies, since *success depends largely on a knowledge of the proper time to begin and end certain timber-cutting or barking operations for the destruction of the broods of the beetles.*

When, as is usually the case, the seasonal-history data have been collected at different latitudes and altitudes within the range of the species, the discussion under each species is based on a probable average. But when the data have been collected in one locality the discussion relates to that locality, and the probable differences are estimated for other localities. While there is yet much to be determined in regard to the rate of difference between different localities at the same latitude or elevation in the same region and the influence which different latitudes and altitudes exert on different species, sufficient evidence is at hand regarding some of the species of this genus and the regions occupied by them to warrant certain preliminary conclusions as a basis for action and further study.

HABITS.

HABITS OF PARENT ADULTS AND OF IMMATURE STAGES.

All of the species of Dendroctonus will breed to a greater or less extent in the living and dying bark of stumps and logs, and in injured and weakened trees. Some of them show a preference for trees in weakened condition, while others show a preference for healthy trees. *All of those studied, however, have demonstrated their ability to attack healthy trees and kill them whenever the individuals of a species occur in sufficient numbers to overcome the resistance of the tree.* The habit of swarming, or of congregating in one locality and concentrating their attack on groups of trees within a forest, is one of the more striking features in the habits of these beetles. The part of a tree selected for the attack varies somewhat in the different subdivisions of the genus. The species that are more destructive to the life of a tree attack the middle to upper portion of the trunk, while those that are less destructive attack the trunk toward the base, or even at the roots. The beetles' power to resist the repelling effects of the resin that flows into the freshly excavated entrances and galleries in the living bark and to dispose of it by forming pitch tubes at the entrances is most remarkable. This alone demonstrates the ability of these insects to overcome the resistance exerted by a living, healthy tree. The manner of excavating the egg galleries and the directions followed in their extension are quite different among the several species and have a different effect on the tree. The almost transverse, very winding, and closely arranged galleries of species 1, 2, 4, 5, and 6 serve to quickly girdle and kill the trees, while the straight, longitudinal course and parallel arrangement of those of species 9, 10, 11, 13, and 14 result in a much slower, but none the less certain, death of the tree.

RELATION OF HABITS TO SUCCESSFUL CONTROL.

The habits of the broods of larvæ are of special importance in indicating methods of control.

In subdivision A the larvæ of species 1, 2, 5, 6, 7, and 8 excavate their larval mines through the middle layers of the inner bark, so that they are rarely exposed in the inner bark. Those of species 3 and 4 are exposed, but in all of the species of subdivision A the transformations from the larvæ to the pupæ and adults are almost entirely in the outer corky bark, so that in order to destroy the broods of the species of this subdivision the simple removal of the bark is not sufficient; it must be burned or otherwise destroyed.

In the species of subdivisions B, C, and D the larvæ excavate their mines in the inner layers of bark and also transform to pupæ and adults in the inner bark, so that when the bark is removed from the tree they are exposed to the frost or sun and drying winds, which is sufficient to kill them, without the necessity of burning the bark.

It will be seen from the foregoing that the periods in which control operations must be conducted are indicated by the habits and seasonal history of the species involved. In general, the work should be done between the beginning of hibernation in the fall and the beginning of activity in the spring, but in the case of certain species in which there are one or more complete generations within the season of activity, such as species 1, 2, and 4, it may be desirable under certain conditions to dispose of the infested trees during the summer, as well as during the winter, especially during the principal development and summer activity of the first generation of larvæ. In the case of species 9, 10, and 11, the operations may be continued after activity begins in the spring until late in June or the first of July.

SECONDARY INJURIES TO THE TREES.

Some of the losses resulting from secondary injuries or destruction may be mentioned in this connection. One of these which affects the commercial value of the beetle-killed trees is the bluing of the sapwood. This, according to Dr. Hermann von Schrenk, is due to a fungus which finds its way into the wounds and galleries made by the beetles and rapidly penetrates the sapwood to the heartwood, causing at first bluish streaks and later a uniform bluish-gray appearance of the wood. This bluing condition, especially in pine trees infested with species 9 to 11, often prevails long before the leaves of the beetle-infested trees show evidence of decline or death.

Other secondary losses consist in abnormal decay of the sapwood and heartwood, but the greatest losses of this class may come from forest fires started in the beetle-killed timber, which may not only complete the destruction of the old dead and the newly infested timber, but also spread into the healthy forests. But there is one redeeming feature in the destruction of the beetle-infested timber by fire, and that is the widespread destruction of the beetles in the infested trees, thus preventing the rapid extension of their ravages which would otherwise occur.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLES.

It is quite necessary that we should have some general and detailed information in regard to the influences upon the beetles of climate, fires, etc., and how certain methods and practices in the management of a forest, or in utilizing its resources, contribute to the multiplication of the destructive enemies of the living timber, and how certain other methods may contribute to their reduction or destruction. There is considerable difference in this respect between different sections of the country and between different species of Dendroctonus, as mentioned under the more detailed discussion of the several species.

CLIMATIC INFLUENCES.

DROUGHT.

It is the common impression that the death of pine and spruce timber in certain sections of the Rocky Mountain region is primarily due to a weakened condition resulting from drought and that the work of the insects is secondary. Under the influence of exceptionally severe drought during several successive seasons this may be true to a very limited extent, but our observations lead us to conclude that drought does not offer specially favorable conditions for the multiplication and destructive work of barkbeetles. In fact, the reverse is more likely to be the rule, since exceptionally dry conditions appear to be more unfavorable for the development of the beetles than humid conditions. The only exception we have noted in which injury is greater in dry sections than humid ones is that of the Douglas fir. In the more southern range of this tree, where the normal dry character of the climate and soil prevails, it suffers more from the Douglas fir beetle (No. 13) than it does in the Northwest, where, under moist conditions and rich soil, the tree reaches its best development. This beetle is very abundant in the Northwest, yet as a rule it confines its attack to the felled and injured timber and rarely attacks the healthy trees. On the other hand, the western yellow pine suffers more severely in the humid sections than it does in the more arid ones, as demonstrated by the work of the Black Hills beetle (No. 10), which is widely distributed over the eastern section of the Rocky Mountain region, yet has been far more aggressive and destructive in the Black Hills National Forest than in the much drier sections in southern Colorado and northern New Mexico and Arizona, and has continued its depredations in the Black Hills unabated through excessively wet as well as excessively dry seasons.

The western pine beetle (No. 1) is far more abundant and destructive in the northern and more moist climate of the mountains of Idaho, Oregon, and California than is its near relative, the southwestern pine beetle (No. 2) in the drier forested areas of New Mexico and Arizona. The mountain pine beetle (No. 9) is exceedingly destructive to the lodgepole pine at high altitudes and under especially moist conditions. The same may be said of the eastern spruce beetle and the Engelmann spruce beetle. It is evident, therefore, that drought is not an important factor in contributing to the multiplication or destructiveness of this class of enemies.

LOW TEMPERATURE AND SNOW.

While the severe cold at the high elevations in which most of the western species prevail appears to have no detrimental effect on the overwintering broods, we have a striking example of its effect on a northern migration of a southern species, in the complete extermination of the southern pine beetle (No. 4) in the Virginias by the exceptionally cold winter of 1902–3. On the other hand, snows, when sufficiently heavy to break down a large amount of timber, might offer favorable conditions for the multiplication of some of the species like the western pine beetle, the mountain pine beetle, and the Douglas fir beetle.

LIGHTNING.

In certain sections of the country where a great many pine and spruce trees are struck by lightning during the summer months these trees furnish exceptionally favorable conditions for the perpetuation and multiplication of the pine and spruce beetles. Although the constant supply of such trees furnishes also favorable conditions for the multiplication and perpetuation of the natural enemies of the destructive beetles (insects and birds), these enemies are frequently not sufficiently numerous to serve as a natural check, and the living timber is attacked by the broods of beetles which develop in the lightning-struck trees. This is especially true in the Southern States, where a pine tree struck by lightning attracts the beetles to the spot, and they not only enter the injured tree but attack and kill a number of those surrounding it.

WINDSTORMS.

Whenever a windstorm occurring during the period from June to August is sufficiently severe to fell and break a large amount of pine and spruce, favorable conditions may be presented for the multiplication of certain of the destructive beetles, provided they are present in the locality in sufficient numbers to infest the felled timber. This has been demonstrated from time to time in Europe, where beetles with much less aggressive habits than the Dendroctonus beetles have, it is said, been thus enabled to multiply to sufficient numbers to attack and kill the living timber and cause serious extension of their depredations into the healthy forest.

OTHER INFLUENCES AND CONDITIONS.

FOREST FIRES.

While some of the species find favorable conditions for their multiplication in fire-scorched trees, others, like the Black Hills beetle, appear to prefer the uninjured trees. This is due, perhaps, to the fact that if a fire be sufficiently severe to kill large pine trees, the bark on the lower and middle trunk is so scorched and killed that the beetles can not live in it. Spruce, however, may be killed or weakened from injuries to the base and roots by a surface fire, and thus offer especially favorable conditions for the multiplication of the spruce beetles. On the other hand, a forest fire in a forest in which the majority of the trees are infested by broods of beetles and dying from their injuries may contribute to the destruction of the insects and the protection of the remaining living timber.

MATURED TIMBER.

Practically all of the more destructive species show a decided preference for the larger and best-matured trees, and as a rule these are killed first, and the younger timber is not attacked until later, if at all. This is particularly true of the spruce beetles (Nos. 14 and 15), the southern pine beetle in the East and South, the western pine beetle, and the mountain pine beetle of the West.

COMMERCIAL CUTTING.

The cutting of living timber for commercial purposes may offer favorable conditions for the multiplication of some of the species, like the Douglas fir beetle and western pine beetle, but if such cutting, within a range of less than 50 square miles, is more or less continuous, it appears to serve as a protection to the living timber rather than otherwise. On the other hand, local sporadic cutting may bring about more or less serious results. Some species, like the Black Hills beetle, are evidently not attracted from the living trees by cutting operations, while the southern pine beetle in the Southern States is greatly favored by sporadic cutting, especially if carried on during the summer months.

SUMMER CUTTING.

The cutting of healthy trees, or even of living beetle-infested trees, during June, July, and August, in a forest or section where the southern pine beetle, the western pine beetle, the mountain pine beetle, or even the Black Hills beetle, is present, is more or less objectionable from the fact that the beetles are attracted by the odor of the exposed bark and wood and often attack many healthy trees in the immediate vicinity of the felled ones.

WINTER CUTTING.

When any of the more destructive beetles are present in a forest it is important that the principal timber-cutting operations should be carried on during the late fall and winter months, and completed in the spring before the beetles begin to fly. This is especially important when there is a large amount of infested timber to be utilized, because it is necessary to remove the bark from the trunks of such trees or convert them into lumber and burn the slabs before the insects begin to emerge. Winter cutting of living, healthy timber is much to be preferred when species with a single generation, like the mountain pine beetle, Douglas fir beetle, or the spruce beetles, are present, because during the following summer the stumps and slash will serve to attract the beetles away from the living trees. And since the broods would remain in the bark during the following winter they can then be destroyed by burning the slash any time during the following fall or winter. In the Southeast and in the Rocky Mountain region, however, when species with more than one generation annually are present, it may be necessary to burn the winter slash before the first of July, to destroy the broods of the first generation which develop from eggs deposited during May or June.

NATURAL ENEMIES OF THE BEETLES.

Were it not for the natural checks and control of some of the insect enemies of forest trees, the destruction of the forests would evidently be far more continuous and complete, but under the existing warfare between the trees and the destructive beetles and between the beetles and their own enemies, a more or less balanced condition in nature is preserved, so that it is only under exceptional conditions that a species of tree or a species of insect is exterminated.

INSECTS.

The insect enemies of the destructive beetles consist of parasites, predators, and robbers. The parasites are small wasplike insects.[a] The adults lay their eggs on, in, or near the beetle larvæ, and the minute maggotlike larvæ of the parasite, situated either internally or externally, feed on the body fluids and thus cause the death of their victims. When the parasite larva reaches its full development it either changes to a free pupa in the mine of its victim or makes a cocoon in which it goes through its transformation. Therefore the presence of certain of the parasitic enemies of the beetle larvæ is indicated by the presence of their cocoons in the mines, even after their victims have been destroyed and they themselves have emerged.

The principal predators consist of certain adult beetles and their larvæ[b] (see fig. 32), the adults often feeding on the adults of the destructive beetles before or after they enter the bark, and the larvæ feeding on the broods of the beetle larvæ in the bark.

There is another class of predatory enemies of the beetles among the true bugs,[c] which follow the beetles and larvæ into their galleries and mines, and kill their victims by inserting their beaks into their bodies.

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[a] Order Hymenoptera, families Braconidæ, Chalcididæ, etc.

[b] Order Coleoptera, families Cleridæ, Histeridæ, Trogositidæ, Colydiidæ, etc.

[c] Family Anthocoridæ.

The so-called robbers (see fig. 30) consist of large bark-boring grubs or larvæ of long-horned beetles,[a] which sometimes rob the barkbeetle larvæ of their food supply or kill them outright, by destroying the inner bark before the broods of barkbeetles have completed their development. These, however, do not occur so commonly with the more destructive barkbeetles as with those which, like the bark-boring grubs, are in the bark as the result, and not the cause, of the dying condition of the tree.

While some of the Dendroctonus beetles have numerous insect enemies, others have comparatively few. Some of the smaller species, like the southern pine beetle, which often occupy the thin bark on the upper portion of the trunk and branches of the larger trees, and sometimes on young trees, have many parasitic enemies, while others of the small species, as 1, 2, and 5, and the larger species, such as the Black Hills beetle and the Douglas fir beetle, which usually occupy the thick bark, have none at all, or very few.

So far as determined, the southern pine beetle has 11 parasitic and about an equal number of predatory enemies; the eastern spruce beetle has 5 parasitic and 4 predatory enemies, and the eastern larch beetle 6 parasitic and 2 predatory enemies. Of the western species the mountain pine beetle is the only one on which a parasite has been found, but there are four or five predators common to all, which evidently exert quite an important influence in protecting the forests of some sections. With a little assistance on the part of the owner of the forest, this class of beneficial insects will exert a much more powerful influence in preserving a desirable balance among the contending forces, and thus prevent destructive outbreaks of the beetles. This balanced condition appears to prevail at the present time within the range of the southern pine beetle, and with proper attention to local outbreaks of the beetles it could be maintained. However, this whole subject of parasites and predatory enemies of forest insects and their economic relations is one which has not as yet received the attention it deserves. Mr. Fiske gave the matter considerable attention during his field work in forest insect investigations, but his detail to another branch of the Bureau prevented him from continuing it.

BIRDS.

Wherever the Dendroctonus beetles have been found in standing timber the work of woodpeckers has been more or less common, and in some trees quite a large percentage of the beetle broods has been destroyed by the birds. The evidence gathered in Maine a few years ago indicates quite conclusively that the birds were rendering a most valuable service as a natural check to the multiplication and destructive work of the eastern spruce beetle. The work of birds is common in sections where species 1, 9, and 10 and other western species are prevalent. Yet birds evidently render the greatest service where but few trees are being killed, since their concentrated work may prevent an abnormal increase of the beetles; but where many hundreds or thousands of trees are being killed, the limited number of birds can have little or no effect. Therefore, while the birds are among the foresters' valuable friends, they can not, even with the utmost protection, always be relied upon to protect the forest from its insect enemies. We must remember that there are most complex interrelations between birds, the injurious insects, the beneficial insects, the enemies of the birds, etc., which do not always result in benefit to the forest. In fact it is often quite the reverse. Therefore, in order for the forester or owner of the forest to derive the greatest benefit from the conflict, he must not only direct his efforts toward utilizing as far as possible the natural factors which are contributing to his personal interests, but whenever the enemies of the forest threaten to get beyond natural control he must enter the fight and by radical artificial means force them back to their normal defensive position.

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[a] Family Cerambycidæ.

DISEASES OF THE INSECTS.

While evidence has frequently been found of the work of fungous or bacterial diseases in destroying the adults and immature stages of the beetles, the matter will require detailed study by specialists on such diseases before any definite conclusions can be formed in regard to their economic relations or importance.

DISEASES OF THE TREES.

Evidence has been found from time to time that the primary cause of the death of isolated large and small trees and saplings was some fungous disease of the roots and base of the stem, and that the larger trees so affected sometimes favored the multiplication of a destructive insect enemy. Evidence has also been found that certain diseases of the inner bark and sapwood, like the bluing fungus studied by Dr. Hermann von Schrenk,[a] are sometimes very injurious and destructive to the developing broods of the beetles. It is also apparent that this fungus, which is said to depend largely on the wounds made by the beetles in finding its way into the living bark and sapwood of the standing timber, may also contribute to the more rapid and certain death of the trees. Therefore this interrelation between plant diseases and insects must often be considered in our efforts to locate the primary cause of a trouble.

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[a] The "Bluing" and the "Red-Rot" of the Western Yellow Pine, with Special Reference to the Black Hills Forest Reserve. By Hermann von Schrenk. Bul. 36, Bureau of Plant Industry, 1903.

It has been conclusively determined, however, that *when the beetles occur in sufficient numbers, they are entirely independent of the aid of other factors or the influence of their enemies, and that they attack and kill perfectly healthy timber over extensive areas.*

SECONDARY ENEMIES OF THE TREES, AND DEPENDENTS, GUESTS, ETC., OF THE DESTRUCTIVE BEETLES.

As soon as the attack of one of the destructive beetles causes a weakened or dying condition of a tree, such a tree becomes at once the breeding place of many other species of barkbeetles and bark and wood boring grubs which can not attack healthy trees. These secondary enemies of a tree are dependent on the more aggressive Dendroctonus beetles or on other factors that may cause a similar weakened or dying condition of the trees. Some of them render special service to the destructive beetles by attacking the twigs, the branches, and the unoccupied bark on the upper and lower portions of the trunk, and thus aid in bringing about the certain death of the tree. There are some insects which live in the galleries with the adult beetles, in the relation of guests, others as scavengers, etc., so that it is always important to distinguish which are the real primary enemies, which are secondary, which are beneficial, and which are neutral in their relation to an affected tree.

GENERAL METHODS OF CONTROL.

While the subject of control is treated under the special discussion of each species, there are some general principles and features which should be mentioned in this connection, especially such as relate to the infestations of standing timber by the broods of the destructive beetles.

HABITS AND SEASONAL HISTORY AS SUGGESTING METHODS OF CONTROL.

Any systematic plan or method for the destruction and control of these beetles, in order to be least expensive and most successful, must be based on a knowledge of the habits and seasonal history and many other essential features relating to the particular species, or group of allied species, involved in a given problem. The principal facts of importance in this connection are as follows: (*a*) It is the normal habit of all of the species to infest the bark on the main trunk of the larger to medium sized trees; (*b*) in all species the developing broods of larvæ live in the inner bark; (*c*) some of the species, as in subdivision A, enter the outer dry bark to transform to adults, while others, as in subdivisions B, C, and D, transform in the inner bark; (*d*) the broods of all of the species pass the winter in the bark of the infested trees and remain there until they develop to the winged stage, when they leave the then dying or dead trees to fly and attack the living ones; (*e*) the developed broods of beetles usually emerge from the trees before the leaves are all dead, or certainly by the time the leaves have all changed to the reddish-brown color and begin to fall or have entirely fallen from the branches. (See fig. 25.)

DESTRUCTION OF THE BROODS.

Since the trunk of the tree is the principal part of attack, we have only to direct our efforts to the infested bark on the main trunk, and adopt the method of killing the broods which, under local conditions and facilities, is the most practicable and efficient.

In species 1 to 8 removing the infested bark, and burning or otherwise destroying it, is necessary to kill the developed broods of larvæ, pupæ, and adults which may be located in the outer bark.

In species 9 to 23 the removal of the infested bark without burning is all that is necessary. The time to do the work in both cases is from the time activity ceases in the fall until two or three weeks before the normal time for the winged adults to begin to emerge and fly.

BARKING THE STANDING TREES TO KILL THE BROODS.

The bark may be removed from the standing trees by means of suitable tools (see figs. 57, 58), and the trees left until it is convenient to fell and utilize them. Thus, during the period in which these operations must be done, the labor should be directed exclusively to the removal of bark. If necessary, the barked trees may be left standing for several years without the value of the wood becoming impaired; otherwise their utilization may immediately follow the completion of the barking operations. Whenever the conditions are favorable for the immediate disposal or utilization of the infested timber by sale, free use, or otherwise, the timber may be barked as it is felled and the barked log may be converted into lumber at any time during the year, within the required period.

DESTRUCTION OF THE BROODS WITHOUT REMOVING THE BARK.

The destruction of the broods without removing the bark may be accomplished by several different methods: (*a*) By converting the logs into lumber and burning the slabs; (*b*) by placing the logs in water; (*c*) by piling the trunks and scorching the bark sufficiently to kill the broods; (*d*) by scoring the upper side of the felled trunks to allow the water from rain or melting snow to penetrate the inner bark and thus destroy the broods; (*e*) by transporting the infested trunks a sufficient distance (20 to 50 miles or more away) from the forest and away from any living spruce or pine, so that the beetles emerging from them will find no trees to attack.

ATTEMPTS AT COMPLETE EXTERMINATION OF THE BEETLES UNNECESSARY.

As a rule, it is not only useless but unnecessary to attempt the complete extermination of one or more species of the beetles within a given forest. It is necessary, however, to so reduce and weaken their forces that they can not continue an aggressive attack, thus leaving them to depend upon weakened and felled trees for their support and to occupy a defensive position against their natural enemies.

It must be kept in mind that the beetles must occur in great numbers in order to be successful in their attack on healthy trees. If their number is reduced and kept below that required for killing trees they can do no harm. Therefore in the case of a destructive outbreak it is necessary to destroy only from 50 to 75 per cent of the beetles in order to bring them under complete control.

REQUISITES FOR SUCCESSFUL CONTROL.

The principal requisites for success in dealing with these beetles are: (*a*) Prompt recognition of evidences of their presence before they have extended their depredations beyond a few scattering clumps or patches of trees; (*b*) positive identification of the species involved; (*c*) prompt action in adopting the proper method of control; and (*d*) reliance on expert advice relating to the essential features in the habits and seasonal history of the insects, on which the action is based.

HOW TO CHECK AND CONTROL AN EXTENSIVE INVASION.

If the depredations by species 9, 10, 13, 14, or 15 have spread over a large area and there is yet a large amount of living timber or adjacent healthy forests to be protected, a careful survey should be made in September, October, or November, for the purpose of locating the areas and localities of new infestation in which the trees were attacked during the summer and fall and which, at the time of survey, contain living broods. The areas of principal infestation and the larger patches of infested trees should be designated on a map, and estimates made of the total amount or percentage of timber affected. This will form a basis for definite plans and the organization and equipment of a sufficient force to do the required work within the specified time designated for each species. Then, if regular logging operations can be directed and concentrated upon the principal areas so that a large percentage of the timber can be cut, barked, or otherwise treated before the broods begin to emerge, the desired control may be effected with little additional expense, or even at a profit. If this method can not be adopted, the force should be directed to removing as large a percentage as possible of the infested bark from the standing infested trees or from those felled for that purpose. The first work should be done in the principal areas and larger patches. The work should be planned and executed with the object of destroying the greatest possible number of broods for the time and labor involved; that is, if there are more infested trees than can be barked within the specified time, and five or six times as many insects can be killed by removing half of the infested bark from three or four trees as could be done in the same time by removing all of the infested bark from one tree, the former procedure is far preferable.

HOW TO CONTROL A LIMITED ATTACK.

Whenever it is determined that one or more species is attacking and killing small patches of timber in a given locality or forest of greater or less extent and that the bark of the living and dying trees contains living parent adults and developing broods, prompt and, if necessary, radical action should be taken before the adults begin to emerge and fly.

HOW TO MAINTAIN CONTROL.

IN STATE AND NATIONAL FORESTS.

In State and National forests, and in all other forests in which there is an organized force of rangers and fire wardens or patrols, each officer should be furnished with the necessary instructions for the location of beetle-infested trees and with equipment and directions for taking the necessary action whenever the conditions demand it. It has been demonstrated that any intelligent ranger or manager can become proficient in locating and marking infested trees with comparatively little instruction in addition to that already published or conveyed in special recommendations.

It is not necessary that every isolated infested tree should be treated, but it is of especial importance that all groups of infested trees should receive prompt attention.

IN PRIVATE FORESTS.

Private forests should receive the same attention as reserves, but this is often far more difficult on account of intervening forests, where the owners either can not or will not give the matter the required attention. While in exceptional cases it may be advisable to have laws governing the treatment of timber infested with a dangerous pest, such laws should be based on expert advice and should apply to the more extreme and well-known cases only as a last resort. It is probable that in most cases legislation will not be necessary, and that more ultimate good will result without than with such laws, especially when it can be made clear to the owner that his personal interests demand that he take the proper action and that when necessary his neighbors will render assistance, as is done in the case of a forest fire.

INACCESSIBLE AREAS.

There are yet large inaccessible areas in the East and West where it will not be practicable or possible to control the depredations by these beetles, and which therefore must be left to natural adjustment. While under natural control the matured timber will be lost, it will usually be replaced by young growth, so that under normal conditions the forest will be perpetuated. Under exceptional conditions and combinations of detrimental influences, such as insects, fire, and drought, extensive areas may, however, be completely denuded, never to be reforested under natural conditions. This has doubtless happened in very many denuded and bare areas in the Rocky Mountain region, which were at one time heavily forested.

TRAP-TREE METHOD OF CONTROL.

The well-known attraction of many species of European barkbeetles to weakened, dying, and felled trees suggested to some of the earlier writers on forest insects a method of barkbeetle control which since that time has been widely recommended and under certain conditions and for certain species of beetles has been successfully practiced. It is the so-called trap-tree method, in which living trees are deadened or felled at the proper time or season to attract the insects and induce them to breed in the bark, where they can be easily destroyed by removing the latter or burning the entire tree. Experience and observations indicate, however, that while this method is successful in attracting many species of bark and wood boring insects it does not always attract those which are the most destructive to the living trees, or at least not in sufficient numbers to justify its general recommendation and adoption.

Among the Dendroctonus beetles there are a few species which are attracted to weakened and dying trees and to the stumps, logs, and tops of recently felled living trees. These are species 1, 2, 4, 12, 13, 22, and 23 and, to a more limited extent, species 14 and 15, but extensive experiments have indicated quite conclusively that the Black Hills beetle, the most destructive species of all, can not be successfully attracted to trap trees and that it actually prefers to attack healthy living trees.

The Mountain pine beetle is attracted to a greater or less extent to felled and fire-scorched trees, but will at the same time attack near-by living ones, as will all of the other species. It is therefore under exceptionally favorable conditions only that this method would be sufficiently successful to warrant its adoption as a means of controlling this class of beetles. These exceptions would be as a rule on a very limited scale, as is referred to under the special discussion of some of the species.

One of the objections to the trap-tree method of combating the Dendroctonus beetles is in the fact that a few living trees deadened or felled in the midst of a healthy forest where the destructive species are present may, as has often been demonstrated, not only attract the beetles to the trap trees but to the near-by healthy trees, thus inducing instead of preventing a destructive outbreak.

INTRODUCTION AND PROTECTION OF NATURAL ENEMIES.

The introduction and protection of natural enemies of these bark-beetles is a subject of special interest and one that should receive attention in the future, especially in the line of investigations and experiments to determine facts on which to base reliable conclusions. In the case of a destructive insect which has been introduced from another country it is plain that if its natural enemies did not come with it they should be introduced; but with native insects it is quite a different proposition and will require much detailed investigation before the results from transfers and introductions can be predicted with any degree of certainty. The protection of natural enemies already present is, however, worthy of special consideration. If, for example, certain parasites and predatory insects are abundant in the bark of the infested trees and certain methods of procedure are adopted for combating the destructive beetles which will at the same time allow the beneficial insects to escape, it will naturally operate against the enemy. But if, on the other hand, the beneficial insects are destroyed along with the destructive ones it may have the opposite effect.

The parasites usually attack the broods beneath the thinner bark, like that toward the top and on the larger branches of the large trees or the trunks of the small ones. Therefore, whenever the parasites are common, it will be best simply to remove the infested thicker bark and leave the thinner bark for the parasites.

Burning the infested bark on the trees or immediately after it is removed will destroy the beneficial insects with the injurious ones, but if the bark be removed in the early fall or early spring and left for several days before burning (if burning is necessary), many of the beneficial insects will escape. Or, if it is not necessary to burn the bark, practically all will escape, and thus assist in destroying the broods left in the tops of trees and those in scattering trees. It is always important, therefore, to determine whether or not the natural enemies are present in sufficient numbers to make it worth while to adopt special precautions for their protection.

Wherever woodpeckers are common in a forest they may aid greatly in destroying the broods of barkbeetles in the scattering clumps and isolated trees, especially if the beneficial insects are scarce. If, on the other hand, the beneficial insects are common, the birds may feed on them and do as much harm as good. The protection of the birds, however, should be maintained, because even if they are harmful at times they evidently more than compensate for it in the general service they render to the forest.

IMPORTANCE OF SYSTEMATIC FORESTRY.

After all, success in the control of these beetles and of forest insects in general depends more upon good forest management, perhaps, than upon anything else relating to the practical phases of the problem, for without some organized system of management very little can be accomplished toward the successful utilization of available information or methods of control. It is equally true, however, that unless the available knowledge relating to the insects and the principles of their control is understood and properly utilized in forest management and lumbering operations, nothing will be accomplished, and the depredations and great losses of valuable timber will continue.

SOME RESULTS OF EFFORTS TO CONTROL BEETLE DEPREDATIONS.

It is only within recent years that any detailed work has been done on the forest insects of North America, and the possibility of controlling their depredations is not generally recognized, even among foresters. Organized efforts and definite results were not, therefore, to be expected, yet we have a few examples which may serve as demonstrations of what can be done. In 1900 the eastern spruce beetle was killing a large amount of mature spruce in northwestern Maine. This was investigated and the concentration of the logging operations in the infested sections was recommended. This recommendation was adopted, and with little or no additional expense sufficient numbers of the infested trees were cut the first winter, and the logs floated out in the spring, to check the ravages of the beetles, and, so far as can be learned, up to the present time very little timber has since died in that section as the result of insect attack.

In 1905 the Black Hills beetle was killing patches of timber in the vicinity of Colorado Springs and Palmer Lake, Colorado, as it did in the beginning of the attack in the Black Hills of South Dakota, in 1897, but through the efforts of the late Gen. William J. Palmer and others, sufficient numbers of infested trees were felled and barked on private land and in the adjoining National Forest during 1905 and 1906 to destroy a large percentage of the beetles in the entire vicinity. Careful inspection during the fall and winter of 1906 and 1907 indicates that the pest is now under complete control within a radius of some hundreds of square miles.

The successful control of another serious outbreak of the Black Hills beetle in 1906 on an extensive private estate in southern Colorado was effected through the efforts of the owners in having some 500 infested trees felled and barked within the necessary period to destroy the broods. A large percentage, but not all, of the infested timber was thus treated. This was so successful that not a single infested and dying tree could be found when the area was inspected in 1908. In this, as in the other case, considerable unnecessary expense was involved in the burning of the bark and tops, but the utilizable timber was more than enough to pay all expenses. It is evident that in this case a destructive invasion was prevented, and that more than a million dollars' worth of timber was protected.

The most striking example of success in control of the Black Hills beetle was reported in time for mention in this connection. Mr. W. D. Edmonston, a forest ranger, detailed from the Forest Service to the Bureau of Entomology to work under the instructions of the writer in the location and reporting of evidences of beetle infestation in the National Forests of Colorado and adjoining States, reported in May, 1907, that the pine timber was dying on a large estate not far from Idaho Springs, Colorado, and the adjoining National Forest. He was instructed to make more detailed examinations, after which he reported that some 65,000 feet of timber on the estate were found to be infested by the Black Hills beetle, and that unless the ravages were checked at once the timber not only on this estate but on the adjoining estates and National Forest would be killed. The owner of the property was advised by this bureau to take radical action according to a special recommendation and detailed instructions relating to a necessary control policy. No action was taken, however, before the first of the following July, and therefore not in time to prevent the beetles from swarming from the infested trees and extending their ravages. In December, 1907, Mr. Edmonston was instructed to make another examination of the timber, when he found that his prediction was being fulfilled. He reported that instead of 65,000 feet of infested timber, there was nearly four times as much timber involved in the new infestation, or over 250,000 feet.

The owner was again notified in December, 1907, of the serious character of the outbreak, and the suggestion made that if the logs from the infested trees were converted into lumber and the slabs burned before the next May, it would result in the protection of the remaining living timber. Immediate steps were then taken to carry out the original recommendations. Mr. Edmonston gave instructions to the manager of the estate in locating and marking the infested trees and in the essential features in the methods of utilization to destroy a sufficient number of beetles to check the infestation, and he also marked infested timber on the adjoining estate and National Forest. In May, 1908, Mr. Edmonston reported that the larger clumps of infested trees on the estate had been converted into lumber and the slabs burned, and that those on the adjoining estate and National Forest had been cut and barked. In November, 1908, Mr. Edmonston was instructed to make another inspection of the forest on the estate and surrounding area, and on December 1 he reported as follows:

> Nothing could be more satisfactory than the results obtained by the cutting of the infested timber on the estate. Your recommendations and instructions submitted to the owner, and carefully followed by the manager of the estate, have clearly demonstrated that insect infestation can be controlled and at no expense to the owner of the timber involved: in fact, a very satisfactory price was realized, resulting in a net profit, I understand, of $5 per thousand feet, board measure, on the 240,000 feet cut. This, of course, does not include the profit of the milling operations, but for the logs sold at the mill, after deducting the expenses of cutting and logging. The sawmill was owned and operated by an Idaho Springs firm, and the manufactured article sold in that town. I spent six days on the estate—November 18 to 23. After a very thorough examination of the timber, I found only three infested trees, isolated individuals, over a mile from where the large clumps of infested trees were cut. With the exception of those three trees there is no new infestation on the estate. I also examined the adjoining lands, but no new infestation was observed. The infested trees which I marked in December, 1907, had all been cut and barked. On the Pike National Forest, contiguous to the first-mentioned estate, where, you will remember, I marked some clumps of infested trees, no new infestation was found—not one tree. I found that all the infested trees I marked had been cut and barked. Ranger Kelso had charge of this work, and it has been quite thoroughly done.

This most gratifying result demonstrated two important facts: One, that a very extensive outbreak by one of the Dendroctonus beetles can be controlled without expense, and even at a profit, whenever the conditions are favorable for the utilization of the infested timber; the other, that the essential details, recommendations, and expert advice can be sucessfully carried out by a manager of a private forest and by the rangers of National and State forests. It also indicates quite conclusively that the widespread depredations in the Black Hills National Forest could have been prevented with very little expense to the Government if the matter had received prompt attention in 1901, when the first investigations were made and recommendations submitted. But, through the lack of public appreciation of the importance of the problem at the time, and the lack of sufficient authority and funds later, it was allowed to extend beyond practical control, and in consequence a large percentage of the timber on the entire National Forest has been killed.

DETAILED INFORMATION ON THE SPECIES.

The discussions on the following pages relate to more detailed information on each species.

In the first paragraph, under the English and technical name, will be found a brief summary of the distinctive characters of the species, its seasonal history, habits, distribution, and evidences of attack. This is to facilitate preliminary identification by the reader, and is followed by a more detailed account of the seasonal history, habits, and economic features as a basis for the recommendations and proper application of methods of control, and closed with references to the investigations and identifications on which the statements are based. The fact that the species are discussed more or less independently necessitates some repetition of statements relating to seasonal history, habits, and methods of control. In view of the fact, however, that a bulletin of this kind is used mainly as a reference work, in gaining information on a special insect or subject, as it is required, such repetitions are to a certain extent necessary.

GENERAL EXPLANATION OF DESCRIPTIVE AND OTHER TERMS.

While the illustrations will show the parts designated by technical or semitechnical names, there are other terms used in the discussion of seasonal history, habits, etc., which may need some explanation for the general reader.

Brood.—The term "brood" refers to the progeny of a single pair, or the individuals hatching from the eggs in a single egg gallery.

Generation.—By a "generation" is meant all of the broods that are the offspring of the adults of the overwintering broods, except the overwintered parent adults, which may be parents of the overwintered broods, and also of broods from eggs deposited by them in the spring. Another exception is in the retarded individuals which pass more than one winter in either the larval or adult stage.

All the progeny of the overwintered broods may be said to comprise a complete generation. If all of this progeny complete their development between the time the first eggs are deposited in the spring and the close of the same season of activity, and emerge from the trees, it may be referred to as constituting a complete seasonal generation. If another set of broods develops to maturity from eggs deposited by the adults of the first generation of the season, it will form a complete second generation, and so on. If, however, only parts of the broods complete their development and emerge during the first season, and the others remain over until the next season, it will be a partial development of a seasonal generation. If all of the broods develop and emerge within twelve months from the time the first eggs were deposited, it is referred to as a complete annual generation.

Hibernation.—The term "hibernation" as here applied relates to the period in the seasonal history of the broods from the time general activity ceases in the fall until the time it begins again in the spring. In southern localities there may be considerable activity (feeding and development) of the broods during the warmer days of winter, so that hibernation used in this connection does not mean that the broods are entirely dormant and inactive, but that for the greater part of the time they are.

Overwintering stages.—The overwintering stages are those of the hibernating broods.

Overwintered broods.—The term "overwintered broods" relates to all stages which have passed the winter in the bark of the infested trees, whether active or not. It is, therefore, a better term to use for the barkbeetles than "hibernated broods."

Activity of overwintered broods.—By the "activity of overwintered broods" is meant the feeding, development, transformation, emergence, flight, etc., from the time general activity begins in the spring among the broods which have overwintered in the bark. This activity may extend over several months and overlap the activity of broods of one or more generations. The parent adults that attack the tree too late in the fall to complete their egg galleries usually continue their work of extending the galleries and depositing eggs when activity begins the following spring. Some of the parent adults that have completed their egg galleries in the fall may also live over winter and excavate new galleries when activity begins in the spring. The overwintered broods of young adults include those that transformed to adults before activity ceased in the fall and passed the winter in the pupal cells where they transformed. These are usually the first to emerge and fly in the spring, but sometimes they remain in the bark until the majority of the broods are fully developed. Among the overwintered broods of larvæ there may be all stages from very young or small larvæ to fully developed ones. The latter will begin activity by transforming to pupæ. The immature larvæ begin their activity by feeding and extending their larval mines. Under normal or favorable conditions, the majority of the immature stages of some species will have completed their development and transformed to adults before the overwintered young adults in the same tree have begun to emerge, so that nearly all of them may leave the trees about the same time, but there are always certain trees in which the conditions are not so favorable for normal development. There are also broods from eggs deposited by overwintered parent adults, so that the period of development and emergence of all of the overwintered broods is prolonged and irregular. In fact, some of the overwintered individuals of certain species may not complete their development and emerge until the second season of activity. These retarded broods are not of much economic importance, but they introduce an element of confusion in defining the limits of a given generation. On the other hand, periods of normal or principal development, transformation, and emergence of the broods are of especial economic importance, since a knowledge of them is quite essential for successful control.

Seasonal history.—According to the writer's interpretation, the seasonal history of an insect is the history of the broods of the species from the beginning of activity in the spring of one year to the end of the hibernating or overwintering period in the spring of the next year.

Life history.—The term "life history," as frequently employed, is synonymous with seasonal history, but to be more exact it is the history of an individual from the egg to maturity and death, including its natural enemies, environment, or any other phenomena affecting its life.

Egg gallery (fig. 7, etc.).—The egg gallery is the burrow made by the adult beetles, along the sides of which the eggs are deposited.

Larval mines and pupal cells (figs. 19, 22, etc.).—The larval mines are the food burrows made by the larvæ. The pupal cells are cavities excavated by the larvæ at the end of the larval mines, in which to transform to the pupæ and adults.

Food burrow.—A food burrow is one excavated into the living bark by the adult beetles for the purpose of obtaining food.

Entrance burrow (figs. 79, 99).—The entrance burrows are the holes made by the parent beetles through the outer and inner bark preliminary to excavating the egg galleries.

Ventilating burrows (figs. 79, 99).—Ventilating burrows are the vertical burrows located at frequent intervals in the roof of the egg gallery and extending outward to or near the surface. They are utilized by the parent adults as a place in which to turn around, or in which to pack the boring dust, or through which to eject the dust, as the case may be.

Exit burrows or exit holes (figs. 8, 22).—The exit burrows or exit holes are the clear-cut holes in the outer bark through which the adults of the new broods emerge from the tree.

Boring dust (figs. 79, 99, etc.).—The sawdustlike borings ejected from the egg galleries or packed in them and in the larval mines is referred to as boring dust.

Pitch tubes (figs. 8, 9, 100).—The resin or gum expelled by the beetles from the entrance burrows is often formed into more or less regular masses with a hole through the middle, thus suggesting the name "pitch tubes."

Infested trees.—Trees containing living parent adults or developing broods are referred to as "infested trees."

Fading tops.—The fading or noticeably paler green of the foliage of infested trees is referred to as "fading tops."

Sorrel tops.—The yellowish foliage of trees dying from the attack of the beetles is termed "sorrel tops." It must be remembered that a certain number of the older leaves or needles on the healthy twigs die, turn yellow, and fall each year; therefore this normal condition should not be mistaken for an indication of unhealthy conditions. It is only when the needles of the middle and tip of the cluster turn yellow from the base outward that the dying of the tree is indicated.[a]

Red tops.—The term "red tops" refers to the color of the foliage after the tree is dead, and usually after the broods of destructive beetles have emerged from the bark. This reddish-brown of the adhering pine needles may prevail for one year or more after the trees are dead.

Beetle-abandoned trees.—After the broods of the destructive beetles have emerged from the bark of a tree such a tree is referred to as "beetle abandoned."

Black tops (fig. 25).—The condition of the dead trees after all of the needles have fallen and two or more years after the beetles have left them is referred to under the name "black tops."

Broken tops (figs. 26, 27).—After the trees have been dead four or more years and the tops have broken off they are termed "broken tops."

Sap stain or blue sap (fig. 29).—The discolored condition of the sapwood of infested trees before and after the leaves begin to fade is referred to as "sap stain" or "blue sap."

Sap decay.—After the trees have been dead long enough for the sapwood to be decayed, but the heartwood is yet in a sound condition they are termed "sap decayed."

Heart decayed.—The term "heart decayed" refers to the condition after the trees have become unfit for any practical use.

Millimeters and inches.—One millimeter equals about one twenty-fifth of an inch or about four-hundredths of an inch. Two millimeters equal about one line, or about one-twelfth of an inch. To reduce millimeters to inches, multiply by 0.04; to reduce hundredths of an inch to millimeters divide by 0.04. To reduce lines to millimeters multiply by 2; to reduce millimeters to lines, divide by 2.

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[a] Needles injured by climatic conditions have the tip dead and the base green.

No. 1. THE WESTERN PINE BEETLE.

(*Dendroctonus brevicomis* Lec. Figs. 6–11.)

The western pine beetle is a rather stout, brownish, cylindrical bark-beetle, from 3 to 5 mm. in length, with head broad and grooved, pronotum punctured and but slightly narrowed toward the head, and elytra with fine rugosities, but entirely without long hairs. (See fig. 6.) It attacks healthy, injured, and felled western yellow pine and sugar pine, and is destructive to living timber in the mountains of California and northward and eastward to Washington and Montana. The adults excavate long, winding egg galleries (fig. 7), through the inner layers of living and dying bark. The white, legless larvæ hatching from the eggs excavate short larval mines in the middle portion of the inner bark, the latter rarely showing on the inner surface. Later they transform to pupæ and adults in the outer corky bark. Pitch tubes (figs. 8, 9) are produced on the main trunk of the living trees attacked. The fading to yellowish and reddish foliage indicates its destructive work.

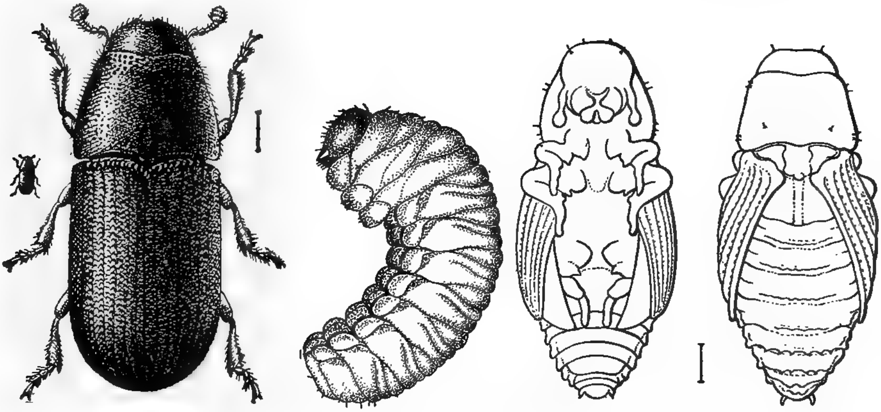

FIG. 6.—The western pine beetle (*Dendroctonus brevicomis*): Adult, larva, pupa, greatly enlarged. (Adult and larva, author's illustrations; pupa, from Webb.)

SEASONAL HISTORY.

OVERWINTERING STAGES.

The broods pass the winter in the outer bark of trees attacked the preceding late summer and fall, as parent adults, young adults in pupal cases, all stages of larvæ, and possibly pupæ.

ACTIVITY OF OVERWINTERED BROODS.

The overwintered parent adults extend their galleries or excavate new ones and deposit eggs during April and May, from which broods develop and emerge by the last of July to the middle of August.

The broods of young adults in the pupal cells begin to emerge from the trees about the last of June, and continue to come out until the middle or last of August. The broods of overwintered larvæ begin to transform to pupæ about the middle of April and to adults toward the last of April, and the latter begin to emerge from the trees about the middle to last of July, so that practically all of them are out by the last of August, although some of the retarded ones continue to emerge until September or later.

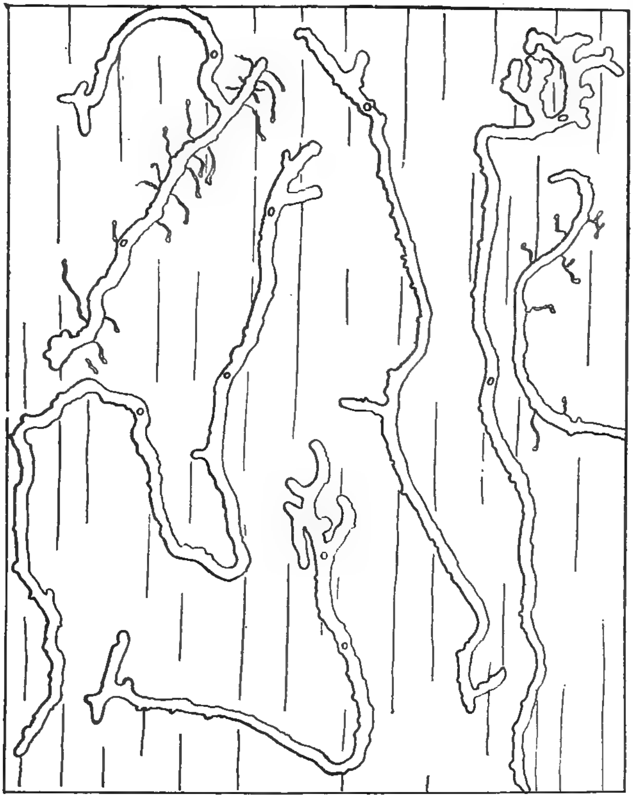

FIG. 7.—The western pine beetle: Egg galleries. Reduced. (Author's illustration.)

FIRST GENERATION.

The overwintered broods of adults begin to attack the trees, excavate galleries, and deposit eggs about the first of July, and continue their activities until September or later. The principal period of attack is during July.

The larvæ begin to hatch in from four to ten days after the eggs are deposited, and may be found in the bark of the same tree from early in July until October, but the principal development is during July and up to the middle of August. They begin to transform to pupæ about the middle of August, and continue transforming until cold weather, the principal period of transformation being from the middle to the last of August. The pupæ begin to transform to adults after the middle of August, and continue transforming until cold weather, but the principal period of transformation is between the middle of August and the middle of September.

The adults begin to emerge from the trees toward the last of August, and continue to come out until in October, or later, but the principal period of flight appears to be from the last of August to the middle of September. While the majority of the broods of this generation emerge before cold weather, it is evident that some of them overwinter in all stages from larvæ to young and parent adults.

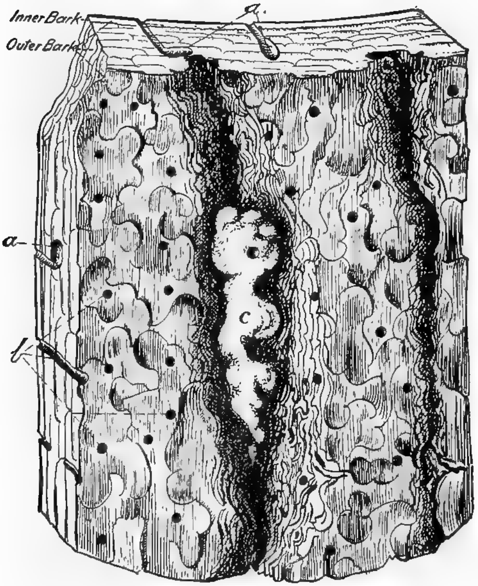

Fig. 8.—The western pine beetle: Bark showing, *a*, *a*, pupal cells; *b*, exit burrows; *c*, pitch tubes. Reduced. (From Webb.)

SECOND GENERATION.

The records of observations indicate that the earlier emerging adults of the first seasonal generation begin to deposit eggs about the last of August, and that the principal period of attack is from the last of August to the middle of September. The larvæ begin to appear about the first of September, and continue to hatch until in October, or later. No evidence has been found that the larvæ of this generation transform to pupæ before winter, but it appears that the broods pass the winter in all stages of larvæ, together with some of the parent adults. Thus, there is one complete generation annually and a partial second one.

HABITS.

The adults attack the living bark on healthy, felled, and weakened standing western yellow pine and sugar pine. They excavate long, winding galleries (fig. 7) through the inner layers of bark, along the sides of which single eggs are deposited at intervals of one-half inch or more. The larvæ normally do not excavate their mines through the inner layers of bark, but through the middle or outer portion of the inner bark. When the larvæ have fully developed, they bore out into the outer corky bark to pupate and transform to adults. After the adults are fully matured, and the proper time has come for them to emerge, they bore out of the bark (fig. 8) and fly to other trees, there to start a new attack. While very few observations have been made on the habits of flight, it is probable that the beetles swarm during the evening and at night.

ECONOMIC FEATURES.

While it appears that this species prefers to attack weakened and felled trees, or isolated healthy ones, it often attacks large numbers of healthy trees and causes extensive depredations. It is especially destructive to the western yellow pine (see fig. 10) in central Idaho, and in the mountains and higher valleys of eastern Washington, Oregon, and California. It must therefore be classed among the important primary enemies of the pines within its range. As a rule, the largest and best trees are attacked, and the winding egg galleries beneath the bark serve to completely girdle them and cause their death before the broods have developed and emerged.

EVIDENCES OF ATTACK.

The external evidence of attack by this species on healthy trees is the presence of pitch tubes (figs. 8, 9) at the entrance of the galleries, or reddish borings lodged in the flakes of bark on the trunk and around its base. Trees attacked in

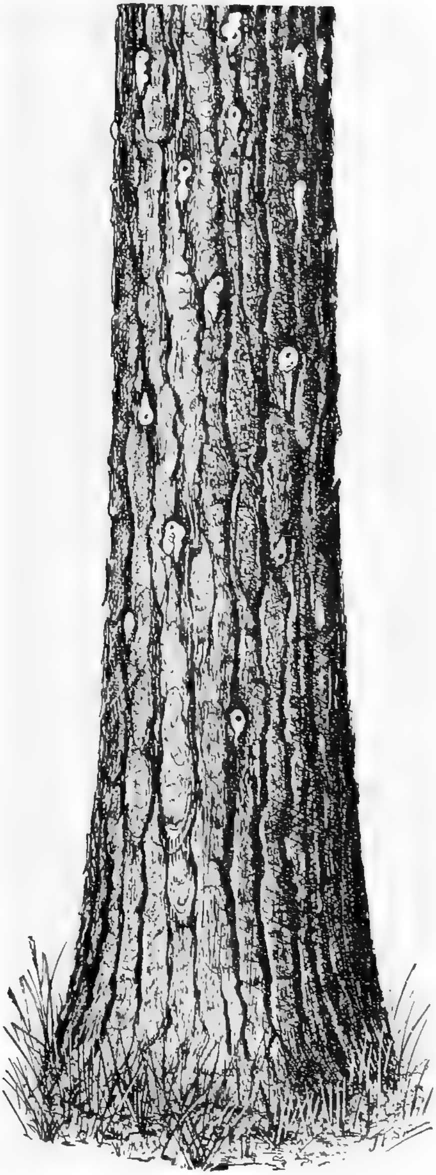

FIG. 9.—Work of the western pine beetle: Pitch tubes on bark of tree. (From Webb.)

July will usually have the foliage fading or turning yellow in August; those attacked in August may have the foliage fading in September and October, while those attacked in September may fade during the late fall or winter or remain green until the following spring. All, however, will have yellow to reddish foliage before the broods have entirely emerged the following July. As a rule, all of the broods will have emerged from the trees found at any season with reddish to brown and falling foliage. The exceptions are when only part of a tree or the bark on one side of the trunk is killed by the first attack, and the remaining living bark is infested later in the same season or during the next. Positive evidence that the above conditions are caused by this species must be based on authentic identification of specimens found in the bark of trees so affected.

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

The commercial value of the wood of trees killed by this beetle is reduced by the bluing of the sapwood, often before the leaves begin to turn yellow, but the heartwood, especially of the larger trees, does not deteriorate until decay sets in several years after the tree's death. The loss, therefore, is not necessarily very great where the timber is felled and utilized immediately after a destructive attack, but if the insect-killed trees are left standing until the branches and tops break off and fall (fig. 10), the loss is often serious or complete. Serious losses of a secondary nature, both of the dead and adjoining living timber, may often result from forest fires started in the dead timber. Therefore the losses, first from the ravages of this species and second by fire, have been severe in some localities.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication and destructive work of this beetle are found in areas of large, matured timber, and especially where such trees are frequently struck by lightning or injured or felled by storms, etc. The unfavorable conditions for attack upon the living timber are found in areas of vigorous, recently matured, or young growth, and where timber-cutting operations are continued from year to year under modern systems of forest management.

METHODS OF CONTROL.

In localities and areas of greater or less extent where it is known that scattering clumps of trees are dying from the attack of this species, the principal clumps of infested trees should be located in September to March, and the infested bark on the main trunk and larger branches removed and burned, or the logs converted into lumber and the slabs burned. This work should be begun not earlier than October and should be completed by the first of June. If at least 75 per cent of the infested trees are thus treated, sufficient numbers of the broods will be destroyed the first year to protect the remaining timber for several years. Then, if all patches of infested timber are subsequently located and barked before the broods emerge, it should serve to keep this enemy under complete control.

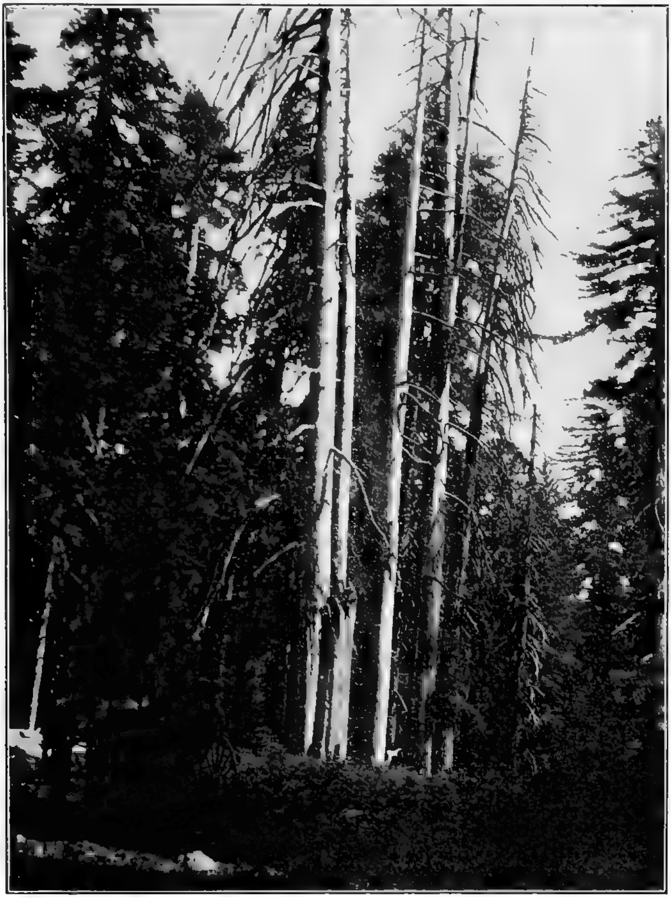

FIG. 10.—Western yellow pine killed by the western pine beetle, Yosemite National Park. (Original.)

Summer operations in the barking of infested trees are not to be recommended, except in special cases where it is desirable to destroy the broods of the first generation. In this case the work should be done during the period of principal larval development—that is, from the middle of July to the middle of August, or when the leaves of the infested trees are just beginning to fade.

It has been determined that this species can be attracted to girdled and felled trap trees. Under certain conditions, therefore—as in the case of the absence of logging operations and where only a few scattering trees are infested—it may be desirable, as a means of maintaining control, to provide a few trap trees to attract the first generation. This can be done by girdling two or three inferior trees to the heartwood or by felling them in June. Then, if they become infested with this beetle, the bark should be removed from the main trunk and burned by the middle of August. Trap trees to attract the second generation should be prepared in August and September and barked before the first of the following May. Usually an average of one to three trees to the acre should be sufficient for this purpose. However, the number will depend largely upon the prevalence of the insect. (See preceding reference to trap trees, pp. 33–34.)

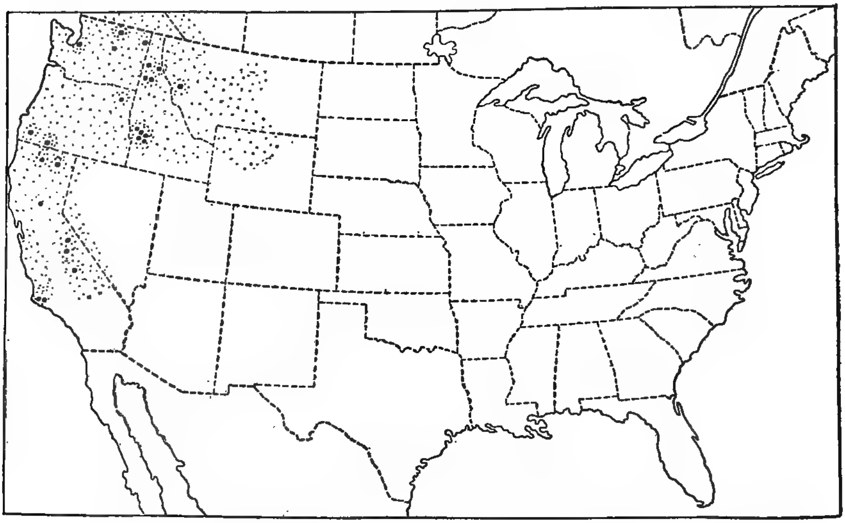

Fig. 11.—The western pine beetle: Distribution map. (Author's illustration.)

Continued timber-cutting operations within an area of from 20 to 50 square miles usually provide sufficient breeding places in the bark of the logs and tops of the felled trees to satisfy the requirements of this species; but if the living timber should be at any time threatened by the broods emerging from the slash, or if it is desirable to include in timber-sale and timber-cutting regulations certain provisions for the burning of the slash, this work should be done about the first of August for the slash of the winter and spring cutting, and during the winter for that of the late summer and fall cutting; the latter period, however, is preferable, on account of the danger of starting forest fires by summer burning.

BASIS OF INFORMATION.

The preceding information on the western pine beetle is based on investigations by the writer at McCloud, Cal., at Grants Pass, Oreg., near Spokane, Wash., and at Moscow, Idaho, April and June, 1899, and in the Yosemite National Park and Yosemite Valley, California, June, 1904; by Mr. J. L. Webb, at Moscow and Troy, Idaho, September and October, 1900, and at Centerville, Stites, Kooskia, Grimes, Placerville, and Smiths Ferry, Idaho, April to September, 1905; by Mr. H. E. Burke, at Smiths Ferry, Idaho, October, 1904, in the Yosemite National Park, at Wawona, and in the Yosemite Valley, California, June to August, 1906, and at Joseph, Oreg., in 1907, and by Mr. V. S. Barber, at Sterling and Chester, Cal., in 1908. Additional localities through correspondence and from other collections are Badger, Ballard, and the Santa Barbara National Forest, Cal.; Winthrop and Auburn, Wash.; Pokegama, Oreg., and Missoula, Mont. The species is represented in the forest-insect collection of the Bureau of Entomology by several hundred specimens.

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Hopkins, 1899*a*, p. 395; Hopkins, 1899*b*, pp. 13, 20, 26; Hopkins, 1901*b*, pp. 66, 67; Hopkins, 1902*c*, p. 21; Hopkins, 1904, p. 18; Webb, 1906, pp. 17–30; Hopkins, 1907, pp. 162–163; Hopkins, 1909, pp. 81–85.

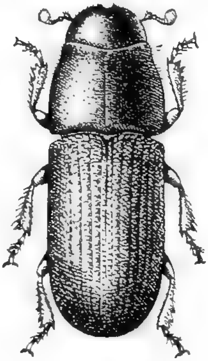

FIG. 12.—The southwestern pine beetle (*Dendroctonus barberi*): Adult. Greatly enlarged. (Author's illustration.)

No. 2. THE SOUTHWESTERN PINE BEETLE.

(*Dendroctonus barberi* Hopk. Figs. 12–14.)

The southwestern pine beetle is a small, rather stout, light to dark brown barkbeetle, from 2.5 to 4.7 mm. in length, with a broad grooved head, sides of the prothorax slightly narrow toward the head, elytra with moderately coarse rugosities, and elytra and declivity without long hairs. (See fig. 12.) It attacks healthy, injured, and felled western yellow pine in southern Colorado and Utah and in the mountains of Arizona, New Mexico, western Texas, and northern Mexico.

The adults excavate winding, transverse, egg galleries (fig. 13) through the inner bark and mark the surface of the wood. The larval mines are rarely visible on the inner surface of the bark, but extend through the middle portion and into the outer corky portion, where the larvæ transform to pupæ and adults. The presence of this species in standing timber is indicated by pitch tubes on the trunk similar to those made by the western pine beetle (figs. 8, 9) and by the fading yellowish to red foliage.

SEASONAL HISTORY.

OVERWINTERING STAGES.

The broods pass the winter in all stages from young to matured larvæ, young adults, parent adults, and possibly pupæ, in the outer bark of trees and logs attacked by the parent beetles the previous summer.

ACTIVITY OF OVERWINTERED BROODS.

The overwintered parent adults begin to excavate galleries and deposit eggs as soon as warm weather permits in the spring, and continue to do so until about the first of June. The overwintered broods of young adults begin to emerge toward the last of May (northern area) and continue to come out until the last of June or later. The overwintered larvæ begin to transform to pupæ and adults soon after activity begins in April or May, but retarded individuals may not develop until in July, or later. The adults from the overwintered larvæ begin to emerge toward the last of May, and continue emergence through June or until the latter part of July, or later. Probably all are out by the first to middle of August.

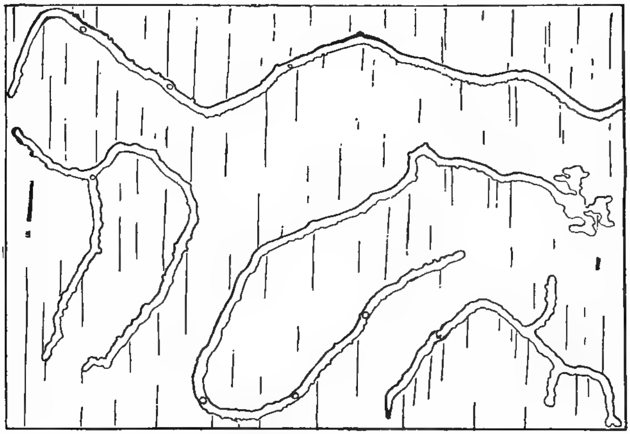

FIG. 13.—The southwestern pine beetle: Egg galleries. (Author's illustration.)

FIRST GENERATION.

The overwintered broods of adults begin to deposit eggs about the first of June and continue doing so until August, or later, but the principal period of attack is during June and July. The larvæ begin to hatch early in June, and begin to transform to pupæ and adults early in July, the principal transformations being in July. The broods of adults begin to emerge about the middle of July, the principal period of emergence being in the latter part of July, but they continue to come out until September, or later. Mr. Webb's observations on the development of the broods from the time eggs were deposited on June 4 and June 9 to the beginning of emergence on July 22 and July 29, show a period from deposition of eggs to emergence of adults of about fifty days.

The principal period of flight of the adults of this generation appears to be during the latter part of July and first of August, but it is evident that while some of the more retarded broods may hibernate as matured adults and larvæ, nearly all develop and emerge before activity ceases in the fall.

SECOND GENERATION.

The records of observations indicate that the earlier emerged adults of the first generation attack the trees and begin to deposit eggs about the first of August, the principal attack being in August and September.

The larvæ begin to hatch early in August and begin transforming to pupæ about the 1st of September, but no adults of this generation have been observed during the first season. The winter is passed in all stages of larvæ, with some of the parent adults. Therefore, there is one complete seasonal generation and a partial development of a second, or two complete generations annually. The principal differences in the seasonal history and generations of species 1 and 2 are the earlier beginning and ending of the first period of attack by the overwintered broods of No. 2, and the more complete development of the second generation. The habits of the two species are quite similar, except that the present species is usually associated with one or more others—Nos. 3, 5, 8, and 10.

ECONOMIC FEATURES AND METHODS OF CONTROL.

The economic features and methods of control relating to this species are quite similar to those of the western pine beetle. In case it should become isolated from the other species of Dendroctonus with which it is usually associated and become independently destructive, and if summer barking of the infested trees should be found desirable, the work should begin (under average conditions) about the middle of June and end at the middle of July, or just a month earlier than for the western pine beetle. The same rule applies for trap-trees for the first generation, which should be prepared in May and barked by the middle of July. The fall and winter work of barking trees may begin a little later, but should be completed by the 1st of May. In the more southern range of this barkbeetle the beginning and completion of such control work should be two months earlier than at the same altitude in its more northern range. (See "Methods of control" under western pine beetle, pp. 46–48.)

BASIS OF INFORMATION.

Information on this species is based on investigations by the writer at Williams, Ariz., September, 1902, at Vermejo, N. Mex., May, 1903, and near Flagstaff, Ariz., May, 1905; by Mr. J. L. Webb at Flagstaff, Williams, and Dead Mans Flat and near the Grand Canyon, Ariz., May to September, 1904, in the Lincoln National Forest at Cloudcroft, and in the Capitan Mountains, New Mexico, and in the Santa Catalina National Forest, Arizona, May to September, 1907, by Mr. W. F. Fiske at Meeks, Capitan, and Cloudcroft, N. Mex., and in the Davis Mountains, Texas, in 1907; by Mr. H. E. Burke at Panguitch Lake, Utah, in 1907; by Mr. W. D. Edmonston at Monte Vista, Colo., in 1907. Additional localities through correspondence are Show Low, Chiricahua Mountains, Arizona; San Bernardino, Cal.; Fort Garland, Colo.; Escalante, Utah, and Santa Fe, N. Mex. The species is represented in the forest-insect collection of the Bureau of Entomology by more than 300 specimens of the insect and its work.

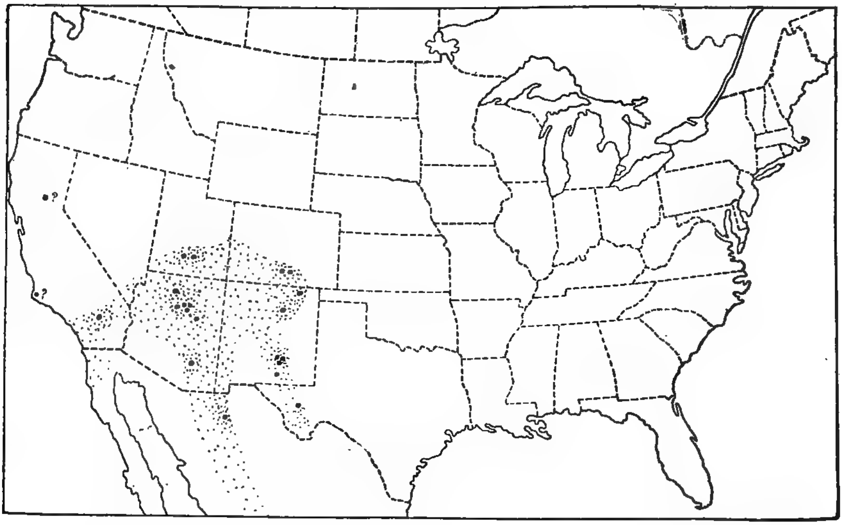

Fig. 14.—The southwestern pine beetle: Distribution map. (Author's illustration.)

This species is closely related to the western pine beetle, but is distinguished by the slightly more slender form, coarser rugosities, and distinctly impressed striæ of the elytra. It is easily distinguished from the other species occupying the same range by the denser rugosities and absence of long hairs on the elytra.

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Hopkins, 1904 (under "The Arizona Dendroctonus"), pp. 42, 44; Hopkins, 1909, pp. 85–87.

No. 3. THE ROUNDHEADED PINE BEETLE.

(*Dendroctonus convexifrons* Hopk. Figs. 15-17.)

The roundheaded pine beetle is a somewhat elongate cylindrical, reddish-brown to black, rather shining barkbeetle, 4 to 6 mm. in length, with the front of the head convex, and without frontal groove, the prothorax broad, only slightly narrowed toward the head, and finely punctured, the elytra with coarse rugosities toward the base, and the declivity with fine punctures and long erect hairs. (See fig. 15.) It attacks injured, felled, and healthy western yellow pine from southern Arizona to northern New Mexico and southern Colorado. It excavates long, slightly winding, longitudinal, and sometimes transverse and branched egg galleries (fig. 16) extending through the inner living and dying bark and grooving the surface of the wood. At intervals along the sides of the galleries single eggs are deposited. The short, cylindrical, grub-like larvæ extend their larval mines at right angles to the egg galleries, usually through the inner layers of bark, and mark the surface of the wood. The transformation to pupæ and adults is sometimes in the inner bark, but probably more often in the outer bark. This barkbeetle is nearly always associated with one or more of four other species of Dendroctonus—Nos. 2, 3, 5, 8, and 10. The presence of this species is indicated by pitch tubes on the trunk and by the fading and reddish foliage.

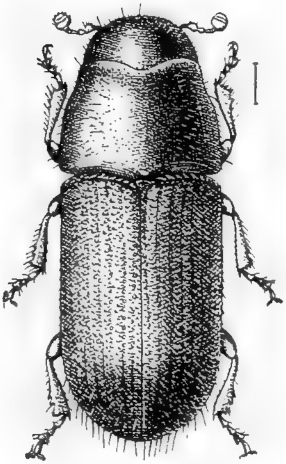

FIG. 15.—The roundheaded pine beetle (*Dendroctonus convexifrons*): Adult. Greatly enlarged. (Author's illustration.)

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed in the bark of trees attacked the preceding summer, as parent adults, young to matured larvæ, young adults, and possibly pupæ, the parent adults in the egg galleries, and the broods in the outer and inner bark.

ACTIVITY OF OVERWINTERED BROODS.

The overwintered parent adults extend the old galleries or excavate new ones from the time activity begins in May until the last of June, or later. The overwintered broods of young adults begin to emerge, probably, in June, and continue to come out until September. The overwintered larvæ begin to transform to pupæ and adults in June and apparently continue to develop and transform to adults until activity ceases in the fall. Some of the adults which have transformed from overwintered larvæ may emerge during the period from August to October, but apparently the majority go over the second winter, together with a few larvæ. Full-grown larvæ observed by Mr. Webb on June 28 had not all transformed to adults on October 10, and only a few adults had emerged. The broods developing from the eggs deposited by the overwintered parent adults may develop to adults before activity ceases in the fall, but the majority evidently pass the winter as medium to matured larvæ.

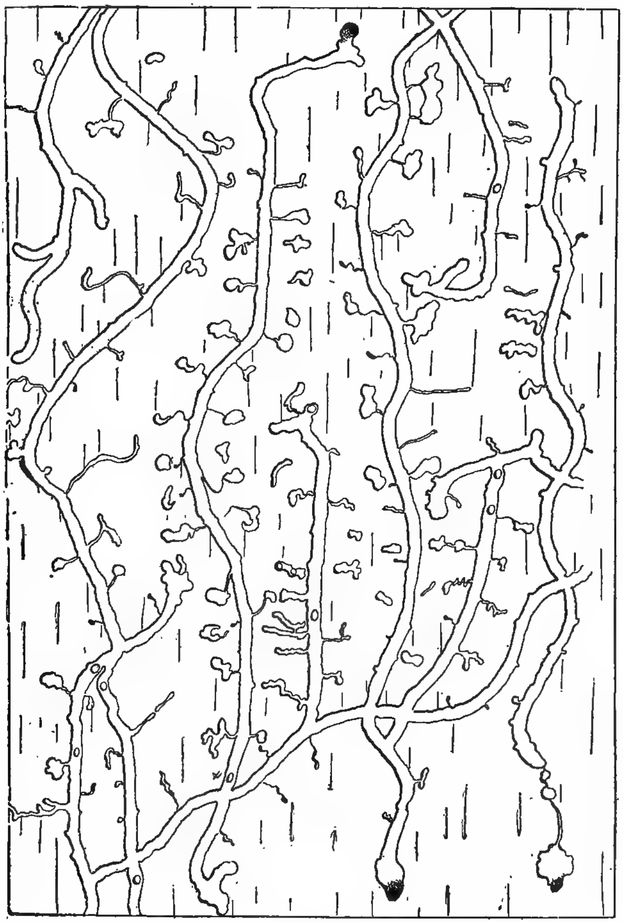

FIG. 16.—The roundheaded pine beetle: Egg galleries and larval mines. Reduced. (Author's illustration.)

GENERATION.

The overwintered broods of young adults begin to emerge and deposit eggs in June and continue to do so until September, or later. Some of the larvæ from these eggs may transform to pupæ and adults before cold weather, but evidently no adults emerge before winter.

It is very evident that there is only one partial generation annually, and that some individuals may not complete their development until the second year. It is evident, also, that the most retarded adults of the first generation may live over and deposit eggs the third year.

HABITS.

So far as known, this species confines its attacks to the western yellow pine, but it is probable that it will attack other species of pine growing within its range. It is nearly always associated with the other species of Dendroctonus and other barkbeetles in injured, dying, and felled trees. The adults enter the living to dying bark on the main trunk of the trees and excavate long, slightly winding, longitudinal, oblique, or nearly transverse and sometimes branched galleries through the inner bark, and often groove the outer layer of wood. In contrast with other species of Dendroctonus which are usually associated with it, except the Black Hills beetle, the larval mines are usually, but not always, exposed in the inner bark, and often mark the surface of the wood. Some of the larvæ may transform to adults in the inner bark, but as a rule they enter the outer corky bark for this purpose. The young adults remain there until time for them to emerge and fly. Nothing is known of the food and flight habits, and many other facts are obscure, owing to the confusion of this with other species before it was recognized as distinct.

ECONOMIC FEATURES.

The fact that this species is usually associated with one or more of species 2, 3, 5, 8, and 10 renders its specific relation to the death of trees doubtful. It is evident, however, that if it should become isolated from the other species and occur in large numbers, it would be fully capable of killing trees on its own account. During the past year it was found associated with the Black Hills beetle in the destruction of a large amount of timber, with evidence that some of the trees were killed by it alone.

METHODS OF CONTROL.

Whenever it is found that this species is causing the death of timber or is associated with other species in doing so, the bark should be removed from the main trunk of the infested trees and burned. The work should be done between the first of October and the middle of the following June. (See also "General methods of control," pp. 29–35.)

BASIS OF INFORMATION.

The preceding information relating to this barkbeetle is based on investigations by the writer at Williams, Ariz., September, 1902, at Vermejo, N. Mex., May, 1903, at Flagstaff, Ariz., May, 1904, and near Ft. Garland, Colo., June, 1906; by Mr. J. L. Webb at Flagstaff, Ariz., May to September, 1904, at Cloudcroft, N. Mex., and in the Santa Catalina National Forest, Arizona, May to September, 1907; by Mr. W. F. Fiske, at Meeks, Cloudcroft, and Capitan, N. Mex., in 1907; by Mr. H. E. Burke, at Panguitch, Utah, in 1907; by Mr. W. D. Edmonston, at Monte Vista and Laveta, Colo., and La Sal, Utah, in 1907. Additional localities through correspondence are Las Animas County, Colo.; Show Low, and Paradise, Ariz., and the Fort Wingate Military Reservation, New Mexico. The species is represented in the forest-insect collection of the Bureau of Entomology by more than 100 specimens of the insect and of its work.

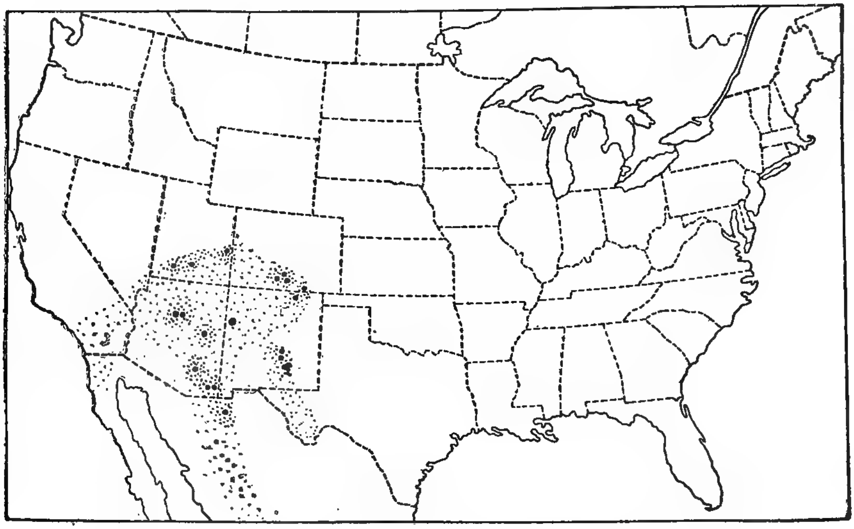

FIG. 17.—The roundheaded pine beetle: Distribution map. (Author's illustration.)

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Hopkins, 1909, pp. 87–90.

No. 4. THE SOUTHERN PINE BEETLE.

(*Dendroctonus frontalis* Zimm. Figs. 18–31.)

The southern pine beetle is a slender, cylindrical, brownish to black beetle, 2.2 to 4.2 mm. in length; the head is broad, with median elevations each side of a distinct frontal groove; the prothorax is punctured and but slightly narrowed toward the head; the elytra have moderately coarse rugosities between indistinct rows of punctures, and the declivity is convex, with a few long hairs. (See fig. 18.) It attacks healthy, injured, and felled trees of all of the pines and spruces, from southern Pennsylvania southward into Florida and westward into eastern Texas and Arkansas. It excavates long, winding egg galleries (fig. 19) through the inner bark, and marks, but does not groove, the surface of the wood (fig. 24). The whitish, legless larvæ excavate short, broad larval mines at more or less regular intervals at right angles along the sides of the egg galleries, usually, but not always, exposed in the inner bark. The transformation to pupæ and adults takes place in the outer corky bark. The presence of this species is indicated by pitch tubes on the main trunk of living trees, and by the fading and yellowish to red foliage as the trees die from its attack. It is a very destructive enemy of southern and southeastern pines.

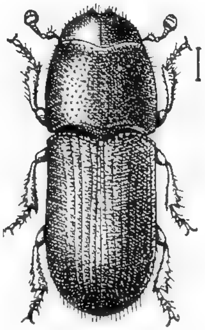

FIG. 18.—The southern pine beetle (*Dendroctonus frontalis*): Adult. Greatly enlarged. (Author's illustration.)

SEASONAL HISTORY.

NORTHERN SECTION.

OVERWINTERING STAGES.

The broods pass the winter in the outer bark of trees attacked during the preceding summer and fall, as parent adults, matured larvæ, and possibly pupæ, and as small larvæ in the inner bark, but principally as matured larvæ in the outer bark.

ACTIVITY OF OVERWINTERED BROODS.

North of South Carolina the overwintered parent adults begin to extend their galleries or excavate new ones as soon as warm weather permits in the spring (March to May) and continue their activities probably until toward the middle of May or later. The overwintered broods of young adults begin to emerge about the first of May. The first swarming period occurs about the middle of May, but stragglers continue to come out probably as late as the middle of June or July. This relates especially to its northern range and to the higher altitudes. The overwintered broods of matured larvæ begin to transform to pupæ and adults in March and April, but the principal transformation is in April, so that the adults are ready to emerge with the overwintered broods of young adults. Some of the broods of overwintered young larvæ probably develop in time to emerge with the swarm, but some of them are generally retarded and do not complete their development until in July, or possibly as late as August. It is evident that the majority of the overwintered broods are out by the middle of June and that all are out by the last of July. Broods from eggs deposited by overwintered parent adults probably develop and emerge by the first or middle of June.

FIRST GENERATION.

The overwintered young adults deposit their first eggs early in May, and the excavating of galleries and oviposition continue probably into June, especially if the parent adults leave the completed galleries to excavate others, which they evidently do, though the general and principal attack by the overwintered broods is from the middle to the last of May. The larvæ begin to hatch early in May and continue their active development during June, the more retarded individuals continuing active into August. They begin to transform to pupæ and adults about the middle of June, and continue until the retarded individuals are all transformed, in August or later. The developed broods begin to emerge toward the last of June and continue to come out during July or until all of the retarded broods and individuals are out in August and September or later; but practically all of the normally developed broods of the first generation are out by the last of July.

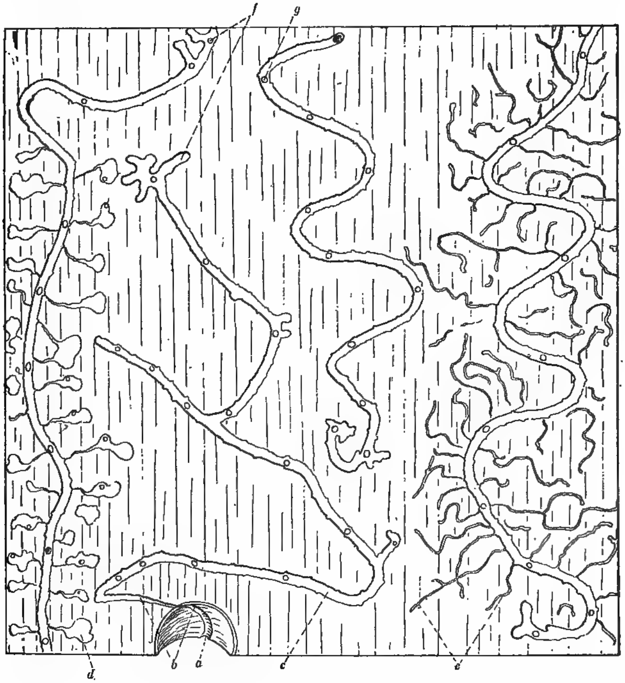

FIG. 19.—The southern pine beetle. Egg galleries and larval mines: *a*, Entrance; *b*, entrance burrow; *c*, egg gallery; *d*, normal larval mine; *e*, abnormal larval mine; *f*, terminal; *g*, ventilating burrows. Slightly reduced. (Author's illustration.)

SECOND GENERATION.

The first eggs of the second generation are deposited by adults of the first generation during the first week of July. The principal attack, however, is during the latter part of July and first of August. The larvæ of this generation begin to hatch about the middle of July, continue to hatch during the latter part of July and early part of August, begin transforming to pupæ and adults during the first half of August, and continue to do so into September or later. The broods of adults begin to emerge about the 10th of August and continue to come out during the middle to last of the month, and until the last of the retarded broods have left the trees, in September or later; but practically all of the normally developed broods are evidently out by the middle of September.

THIRD GENERATION.

The adults of the second generation evidently begin to attack the trees and deposit eggs for the third generation about the middle of August, and continue to do so into September or later, though the principal attack is during the last half of August. The larvæ begin to hatch in a few days after the eggs are deposited, and develop principally during the last of August and first half of September, but some of them do not complete their development before hibernation begins in the fall. The matured larvæ transform to pupæ and adults principally during September, but continue their transformations into November or later. The developed broods begin to emerge about the middle of September, and probably continue to come out until November or later. The majority, however, evidently emerge before the middle of October.

FOURTH GENERATION.

The adults of the third generation evidently begin to attack the trees and deposit eggs about the middle of September, and continue to do so during the latter part of September and first of October, until cold weather. The principal development of the larvæ is during October, practically all becoming full grown before hibernation begins, so that the majority pass the winter as full-grown larvæ in the outer bark. Some of the earliest broods evidently begin transforming to pupæ and adults toward the middle of October, and some of them may emerge in October and November, but evidently by far the larger number of both the young adults and the developed larvæ pass the winter in the outer bark.

FIFTH GENERATION.

There may be a partial or beginning of a fifth generation, especially at the lower elevations and more southern localities of the northern section, the individuals of which pass the winter as parent adults and young larvæ.

It is evident that in the northern section of the range of this species there are from two to three complete seasonal generations during the period from about the first of May until activity ceases in the fall, or at any rate all of the broods of at least two generations develop and emerge during the period of activity within the range including the higher elevations of North Carolina and lower elevations at the northern limit, and that all of the broods of at least three generations develop and emerge at the medium and lower elevations south of Virginia, represented by a central locality included in a range of, say, 1,000 feet above and 500 feet below Tryon, N. C., while portions of the fourth and all of the fifth generation overwinter.

PERIODS OF DESTRUCTIVE ATTACK.

In the area including the mountains of North Carolina and northward there is one principal period of destructive attack, viz, during August and September, and in the area represented by Tryon, N. C., there are two principal periods of destructive attack, one from the middle of July to the last of August, the other during September and October.

Southern Section.

In the southern section, including the Atlantic or Gulf region of loblolly and longleaf pines, there is a complex overlapping of probably five or six generations, most difficult to define on account of the almost continuous activity during the year, but of course more or less retarded during the colder weather of the winter months. It would appear, however, that the principal periods of destructive attack are similar to those of the Tryon section.

HABITS.

The adult beetles enter the living bark, usually on the upper portion of the main trunk of standing healthy or injured trees or on the entire trunk of newly felled ones, and excavate long, sublongitudinal, winding egg galleries (figs. 19–22) through the inner bark. Eggs are placed in little niches along the sides of these galleries at more or less regular intervals of one-half inch or more.

The freshly hatched larvæ, which are short, stout, whitish grubs with a faint frontal elevation in the middle of the head and with the opposite end of the body blunt or truncate, excavate their larval mines at right angles to the egg gallery (fig. 19), and usually exposed in the inner bark. The normal larval mine is first short and threadlike, then suddenly enlarges into a broad cavity, but sometimes, when the bark dies too rapidly or is otherwise unfavorable, a threadlike abnormal larval mine is extended for a much greater distance. When the larvæ are fully matured they bore out into the corky outer bark and excavate individual cells (fig. 22) in which those of the summer brood transform to pupæ and adults and those of the fall broods pass the winter before going through their transformations the following spring. After the adults are fully matured and when the proper time comes for them to emerge, they bore out through the bark and fly away.

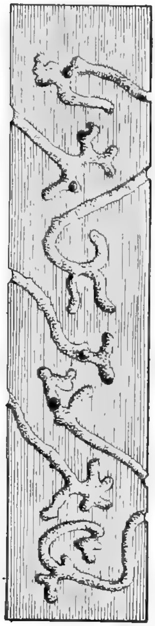

Fig. 20.—The southern pine beetle: Termination of egg galleries. (Author's illustration.)

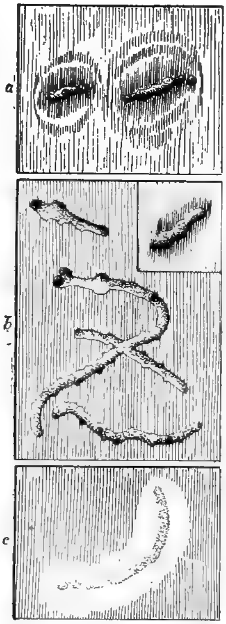

Fig. 21.—The southern pine beetle. Beginning of egg galleries: *a*, In living bark; *b*, in dying bark; *c*, marked on surface of wood (white area represents normal appearance of wood preserved by resin.) (Author's illustration.)

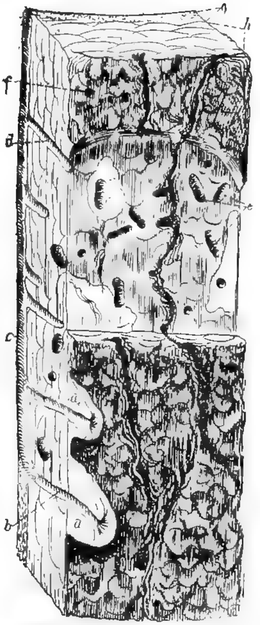

Fig. 22.—The southern pine beetle. Bark showing: *a*, Pitch tubes; *b*, entrance burrow; *c*, egg gallery; *d*, ventilating burrow; *e*, pupal cells; *f*, exit burrows; *g*, inner bark; *h*, outer bark. (Author's illustration.)

The flight or swarming of this species evidently occurs late in the evening and at night, and consequently very few observations have been made on the flight habits. The finding of the beetles in electric-light globes and otherwise attracted to light is conclusive evidence that the beetles fly at night, and the fact that groups of trees are simultaneously attacked by great numbers of the beetles indicates a swarming habit. An especially interesting feature in the congregating habit of the beetles was observed by Mr. W. F. Fiske, who found great numbers congregated under the loose flakes of bark of healthy trees just before their simultaneous entrance into the living inner bark. Another peculiar habit of the beetles is that of migrating from one locality or group of trees where the broods developed to another locality or group of trees some distance away, instead of continuing their attack on the trees immediately surrounding those from which they emerge. Apparently there are rare exceptions to this rule.

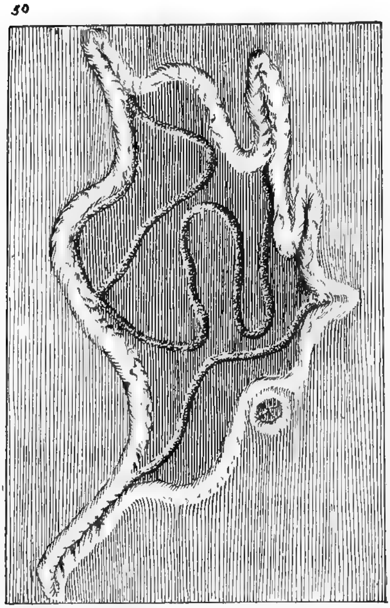

FIG. 23.—The southern pine beetle: Old egg galleries in living tree, with surrounding callus of new wood. (Author's illustration.)

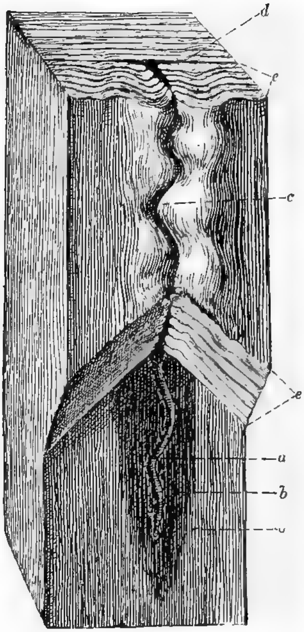

FIG. 24.—The southern pine beetle. Egg gallery in living tree marked on surface of wood six years before block was cut from tree: *a*, Mark of gallery on original surface; *b*, resinous wood; *c*, surface scar six years later; *d*, original surface or 7-year-old annual layer of wood; *e*, six subsequent annual layers of wood formed over original wound. (Author's illustration.)

While this species will breed in injured and felled trees, it shows a decided preference for those living and healthy, whenever it occurs in sufficient numbers to attack and kill them. Its broods of larvæ must have living, or at least partially living, bark in which to complete their rapid normal development. It attacks the bark on the middle or upper trunk of medium to large pine and spruce trees, and usually selects the largest and best trees first. After the larger trees are killed the middle to lower trunk of the smaller trees may be attacked. The habit of attack and methods of excavating galleries are similar to those of the smaller western and Mexican species, all of which extend their galleries from the entrance in a transverse or sublongitudinal and tortuous course through the inner bark (fig. 19). Those of different pairs of beetles frequently cross each other so that the many primary galleries, independent of the larval mines, serve to completely girdle the tree and kill the bark. Thus these winding galleries cause a much more rapid death of the bark and foliage than do the straight longitudinal galleries, like those of the spruce beetles and the Black Hills beetle. The trees are killed by the girdling effect of the winding primary galleries in the bark of the middle portion of the trunk, which, it has been demonstrated, is the most vital part, or at least has less power of resisting injuries than the lower portion and base. Instead of the leaves of the trees remaining green until the next season, as they do on trees infested by the spruce beetle and the Black Hills beetle, all except those on the trees attacked late in the season commence to fade in a few weeks after the trees become infested.

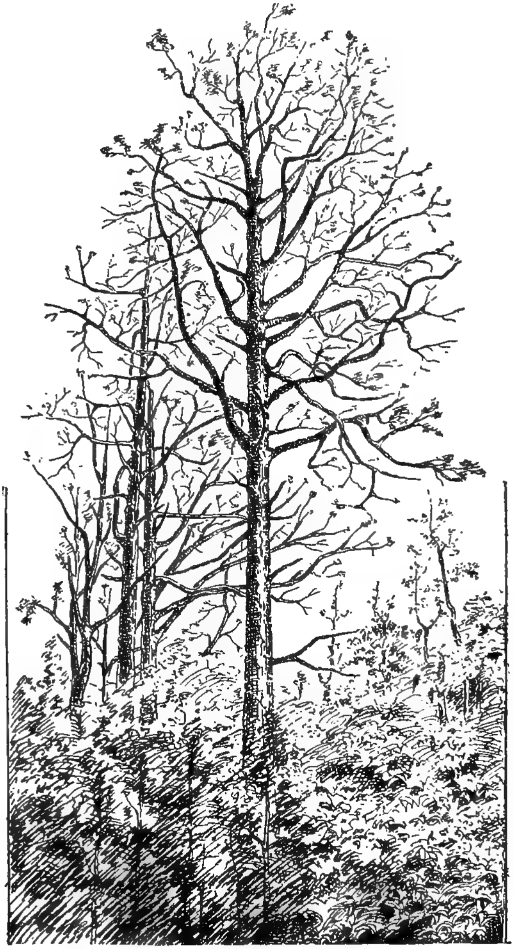

FIG. 25.—White pine timber killed by southern pine beetle Condition in October, 1894, of trees which died in 1891 and 1893. (Original, from photograph.)

ECONOMIC FEATURES.

This species may be considered as one of the most dangerous enemies of the pine forests of the Southern States. It devastated the pine forests over large areas in West Virginia and Virginia in 1891 and 1892, and the extensive dying of pine timber in the Southern States during the past century, to which there are numerous references, was more than likely caused by it. It has been more or less active in the States south of Virginia, southward to Texas, since 1902, and in some localities and during some years it has killed a large amount of timber. It is therefore a constant menace to the pine timber of the Southern States.

EVIDENCES OF ATTACK.

The first external evidence that living trees are being attacked by this species is the presence of pitch tubes (fig. 22) on the upper to middle trunk, or of reddish boring dust lodged in the loose bark and around the base of the trees. If the attack is sufficient to kill the trees, the presence of the insect will be indicated in about two weeks by the fading and yellowish appearance of the leaves, and in about a month after the attack the leaves will be yellowish to reddish, all of the bark except that on the base of the trunks will be dead, and the broods of the destructive enemy will be ready to emerge or will have emerged. After the leaves have become reddish brown practically all of the broods will be out. Positive evidence, however, that the above-described external conditions are caused by this beetle is obtained only by authentic identification of specimens of the insect or its work taken from the affected trees. The presence of the insect in destructive and dangerous numbers is indicated by frequent patches of dying pine or spruce during July, August, and September, and the sudden death of the timber over large areas will indicate a destructive invasion requiring prompt and radical measures for its control.

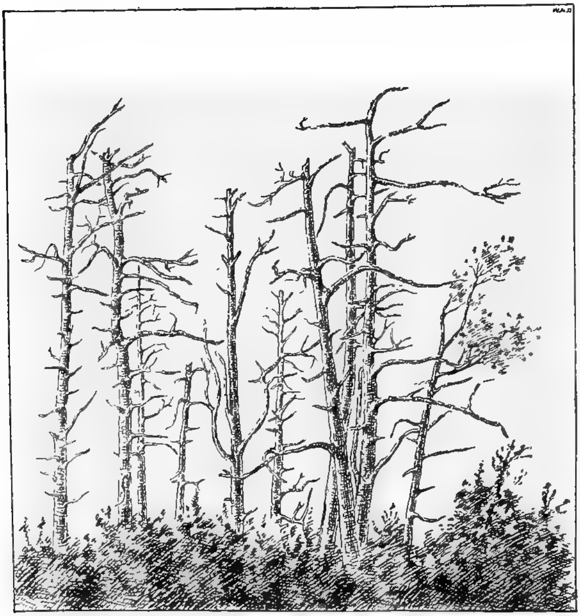

FIG. 26.—Table Mountain pine, Mineral County, W. Va., seven years after it was killed by the southern pine beetle. (Original, from photograph.)

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

The commercial value of the wood of trees killed by this beetle is reduced by the bluing of the sapwood (fig. 29), often before the leaves begin to turn yellow, though the heartwood, especially of the larger spruce and yellow pine, usually remains sound for many years after the trees die; both the sap and heart wood of the smaller trees, and even of the large pitch, loblolly, and Table Mountain pine, deteriorate rapidly (figs. 26, 27), and therefore must be utilized immediately after the trees begin to die, in order to save anything of commercial value.

Serious losses of a secondary nature, both of dead and adjoining living timber, may result from fires started in the dead timber. Therefore the prompt utilization of the beetle-infested trees and the prevention of forest fires are important to obviate total destruction of the timber.

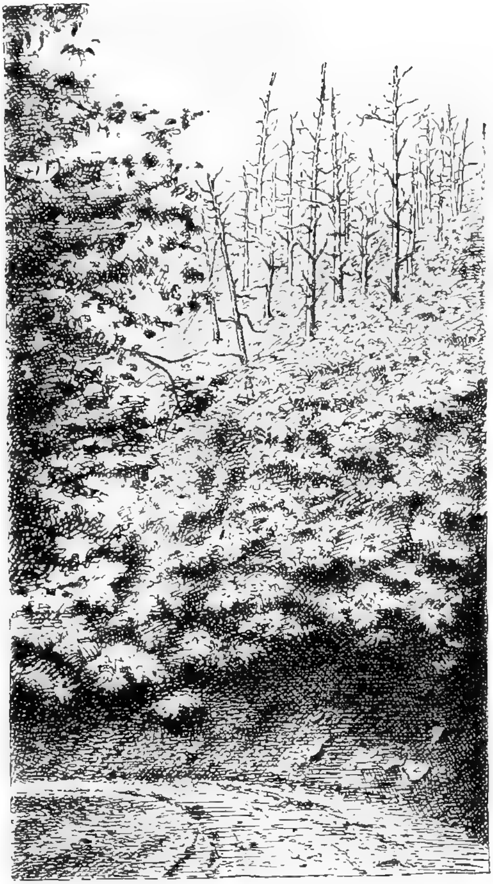

FIG. 27.—A forest of Table Mountain pine, Mineral County, W. Va., seven years after it was killed by the southern pine beetle. (Original, from photograph.)

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication and spread of the beetle are found in areas of large, matured timber and where the trees are frequently struck by lightning, felled, or injured by storms, etc., during the summer months.

The odor from the exposed wood, and perhaps from the wilting foliage of a few trees cut in the midst of a healthy growth of pine during the summer, serves to attract this species, apparently from a long distance, and to induce attack on the surrounding healthy trees. Therefore, any irregular or sporadic local cutting of timber for fuel or any limited purpose during the summer months furnishes most favorable conditions for the concentration of individuals from widely scattered colonies and broods, and thus increases their power of attacking and killing the surrounding living trees. By this means their forces are greatly augmented, and much of the surrounding timber is killed. If conditions favorable for the continued concentration of the beetles prevail from year to year, an invasion like that of 1891 and 1892 may be started, which may far exceed any forest fire in the history of the country, both in the extent of area covered and in the number of trees of commercial value killed.

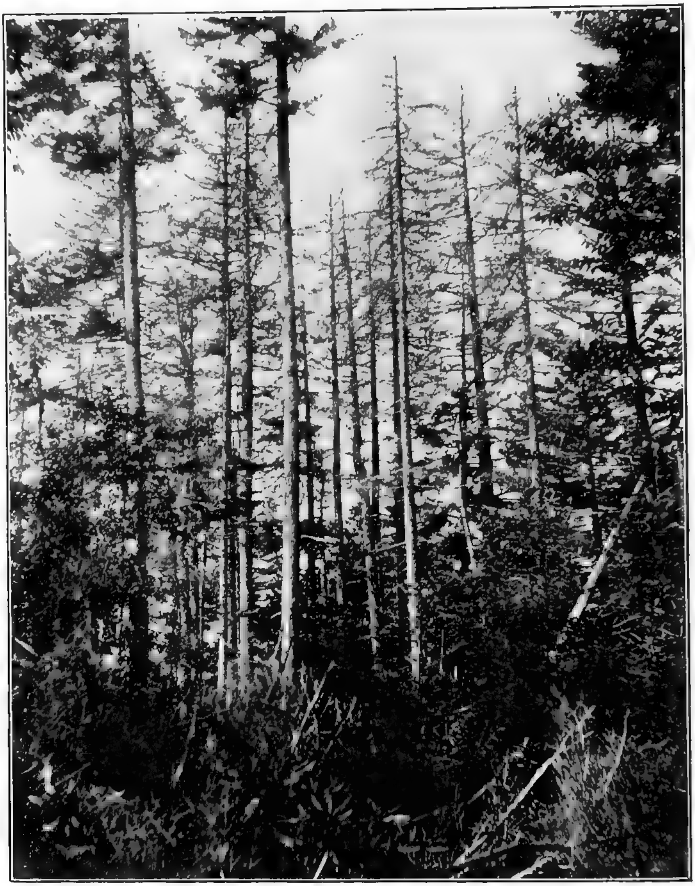

FIG. 28.—Spruce timber killed by the southern pine beetle, mountains of Transylvania County, N. C. (Original.)

Unfavorable conditions for the multiplication of the insect and its destructive attack on living timber will be found in large areas where the older matured trees have been removed and where continued timber-cutting operations are carried on under some regular system of forest management, as also where there are regulations governing the time of year when the timber shall be cut, in both regular and irregular operations, as well as the time when lightning-struck and otherwise injured trees shall be removed or barked.

METHODS OF CONTROL.

In order effectually to destroy the insect, it is only necessary to remove the infested bark from the trunks and burn it. It is entirely unnecessary to burn or otherwise destroy any part of the wood from which the bark has been removed, because the destructive beetle does not enter the wood and rarely breeds in the bark of the tops and branches. With this particular species, however, it is necessary to burn the bark after or before it is removed, because the matured larvæ, pupæ, and adults pass the winter in the outer dry bark, where they would otherwise survive and emerge in the spring, to attack other trees.

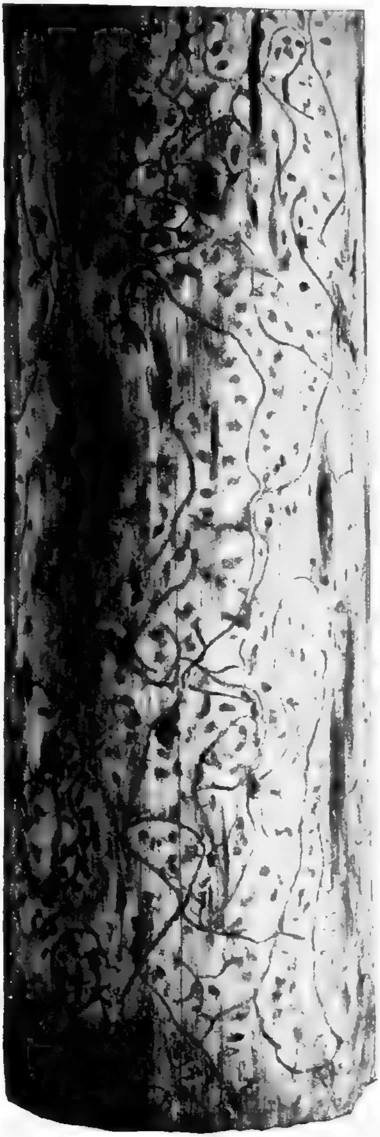

FIG. 29.—The southern pine beetle: Section of pine trunk, bark removed, showing the galleries marked on surface of wood and the dark patches caused by the blueing fungus. (Original.)

In localities or areas of greater or less extent where it has been positively determined that the timber is attacked and killed by this beetle, the principal groups of trees which are actually infested with the broods should be located in the period from November to March, and the standing trees, including all of the larger ones, so infested should have the bark removed from the main trunks or be felled and barked, or the entire trunk scorched, burned, placed in water, or converted into lumber and the slabs burned, as in each case is more practicable or advisable. In the northern section this work should be begun not earlier than the 1st of November and completed not later than the 1st of April, and in the southern section it should be begun in December and completed in February. If at least 75 per cent of the infested trees, including all of those in the larger patches, within 10 or 15 square miles are thus treated, it should destroy enough of the broods to protect the remaining timber for several years. If, then, this practice is followed up

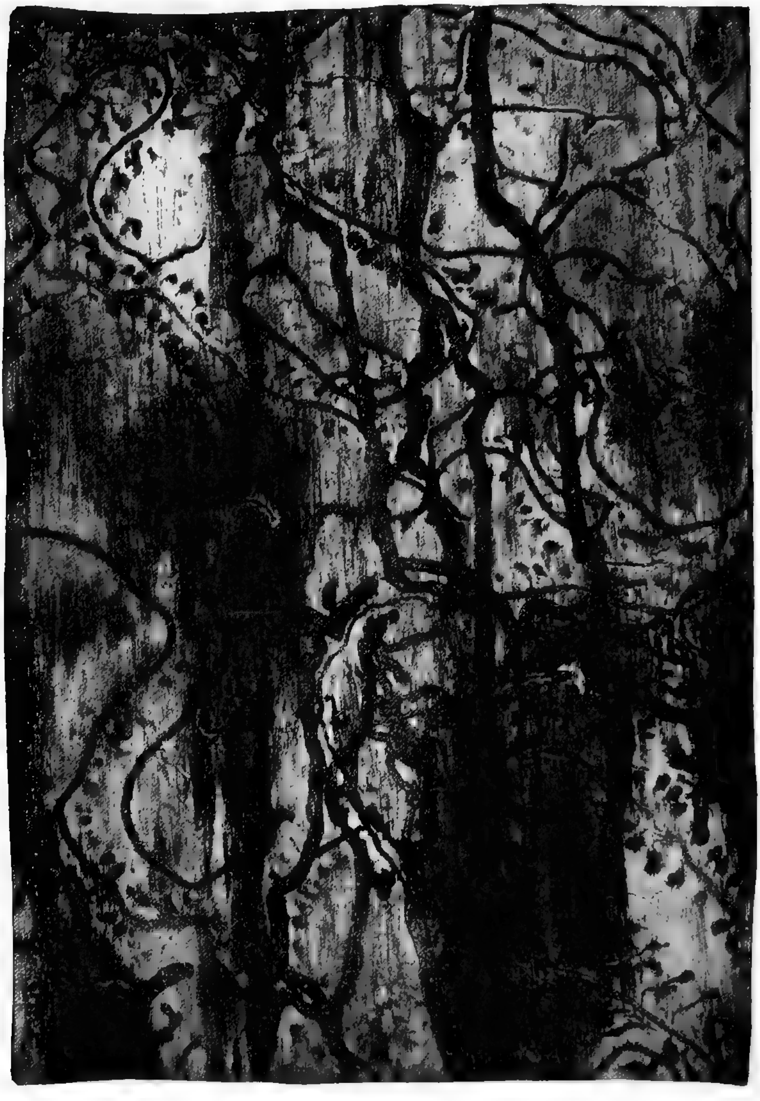

FIG. 30.—Egg galleries and larval mines of the southern pine beetle, and larval mines of roundheaded bark-borer. (Original.)

whenever small patches of infested timber are found it should serve to keep this enemy under complete control.

Summer operations in the felling and barking of infested trees are not to be recommended except in special cases, when, for example, it is desirable under a clear-cutting system to include the healthy timber with the infested, or when practically all of the timber over a large area is infested during the spring and summer; otherwise, if only the infested trees are cut and healthy ones left, the felled and barked trees attract the flying beetles to the locality, and thus the death of a large amount of the surrounding healthy timber results.

If it is desirable to make clear cuttings during the summer, to include small or large areas of infested timber, it should be done during the principal periods of larval development—August and September in the northern section, and from July to October in the southern section.

Whenever it is desirable to protect a small or large estate, or a particularly valuable section of the forest surrounded by forested areas in which the infested timber can not or will not be cut and barked, the greatest precautions should be taken to prevent the cutting of pine timber for any purpose during the spring, summer, and early fall. The only exception would be lightning-struck or storm-broken and felled trees, which, under certain conditions, should be cut and removed, or burned with the tops, if possible, the next day after the injury occurs. If the logs are removed the tops should be burned over the stumps.

If pine cord wood is cut during the summer, it should be done under the clear-cutting system and confined to a section of the forest away from the more valuable timber which it is desirable to protect from insect attack. Cord wood, new lumber, etc., should never be piled in proximity to living pine trees, neither should building operations involving the use of new pine lumber or fresh paint be conducted during the summer in or near a desirable grove of pine or spruce. All of the above relates especially to sections *where the beetle is present in the surrounding forest.*

Some experiments conducted by Mr. W. F. Fiske, while working on forest insects, indicate that if the infested trees are felled in November and December and left flat on the ground and the upper side of the trunk is scored or blazed so as to facilitate the entrance of water from rains and melting snows, the broods will be killed by the abnormal wet condition of the inner bark.

When the infested timber is near streams or ponds the broods may be destroyed by placing the unbarked trunks or logs in the water, provided the work is done before the broods begin to emerge.

Whenever the infested timber can be utilized for lumber the burning of the bark and slabs is all that is necessary.

BASIS OF INFORMATION.

Information on this species is based on investigations by the writer for the West Virginia Agricultural Experiment Station in many localities in West Virginia, July, 1891, to December, 1896; for the United States Department of Agriculture at Fletchers, N. C., July and November, 1902; at Tryon, N. C., July, 1902, March, 1903, and July, 1904; at Boardman, N. C., Inman, N. C., and Kirbyville, Tex., November, 1902; at Pink Beds and Pisgah Ridge, N. C., July, 1904; at Virginia Beach, Va., November and December, 1907, and April, May, and June, 1908; by W. F. Fiske at Tryon, N. C., March to September and December, 1903, April to December, 1904, March to December, 1905, and May, June, and July, 1906; at Clyo, Ga., August, 1903; at Pisgah Ridge, N. C., September, 1903, and September, 1904; at Cornelia, Ga., November, 1903; at Chicora, S. C., November, 1904; at Call, Tex., February and November, 1905; at Beaumont and Deweyville, Tex., Thomasville, Ga., Montgomery, Ala., Wilson and Singer, La., and Pink Beds, N. C., March, 1905; at Ducktown and Wetmore, Tenn., Ellijay, Ga., October, 1905, and Green Bay, Va., June, 1906. Additional localities through correspondence and from other collections are Calhoun, Ala.; Green Bay, Cobbs Island, Glen Allen, and Auburn Mills, Va.; Hampton, Ark.; Demorest, Ga.; Indian Territory, and Haw Creek, Fla. The species is represented in the forest-insect col-

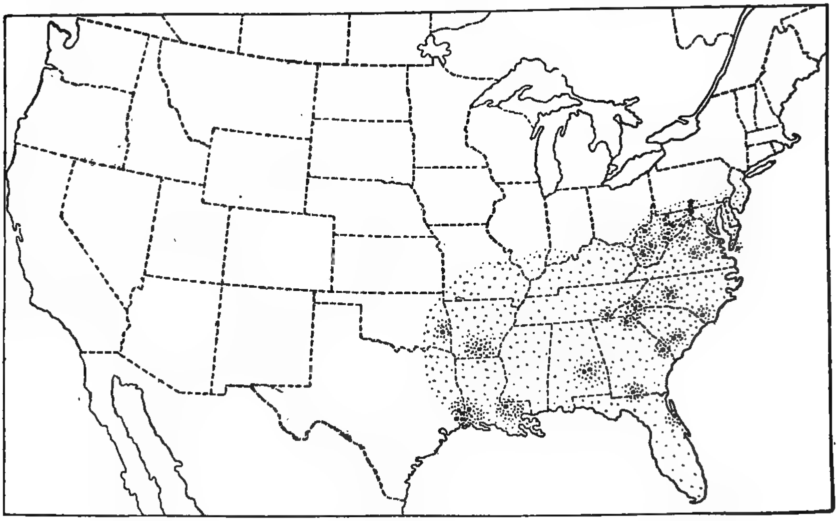

FIG. 31.—The southern pine beetle: Distribution map. (Author's illustration.)

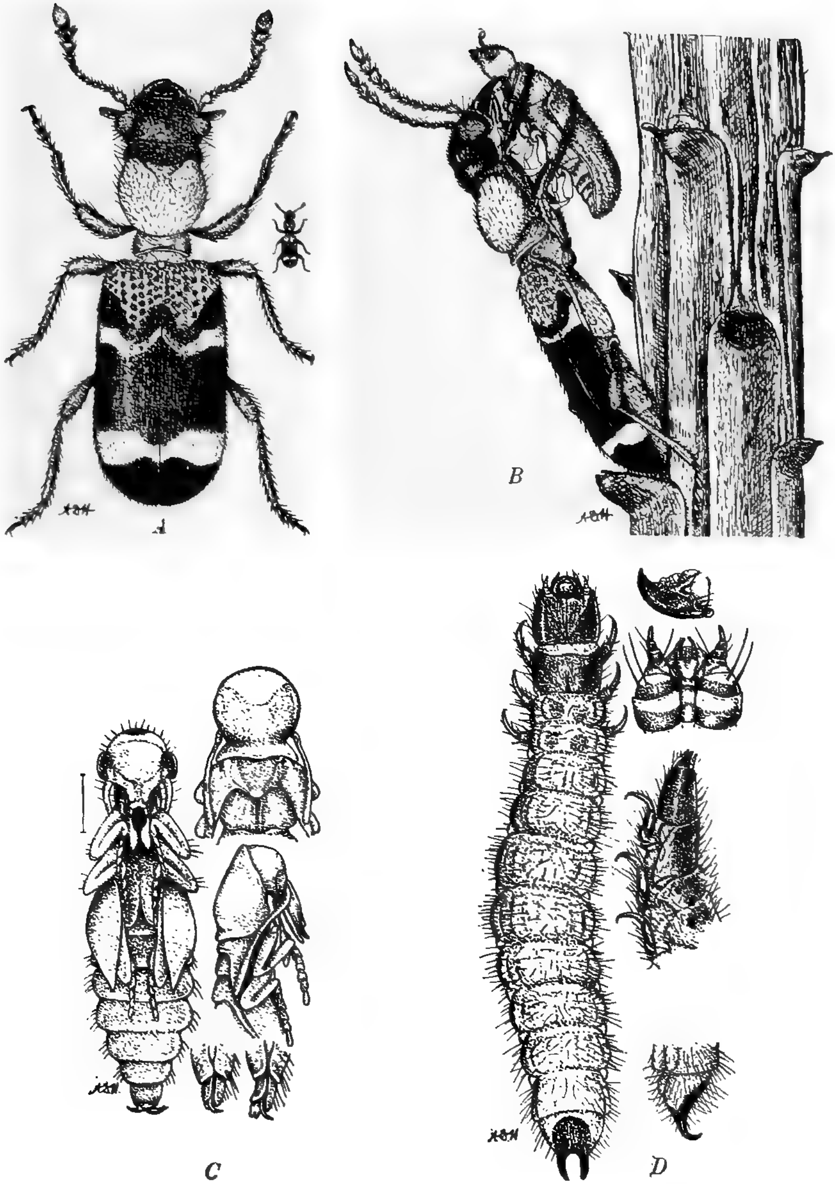

FIG. 32.—The European barkbeetle-destroyer (*Clerus formicarius*), introduced from Europe in 1892–1893:[a] *A*, Adult, dorsal aspect, natural size at right; *B*, adult, showing attitude when feeding on barkbeetle; *C*, pupa and details; *D*, larva and details. Greatly enlarged. (Author's illustration.)

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[a] Hopkins, 1899*a*, pp. 297–231.

lection of the Bureau of Entomology by 65 specimens in the West Virginia Agricultural Experiment Station collection and by more than 150 in the general Bureau of Entomology collection.

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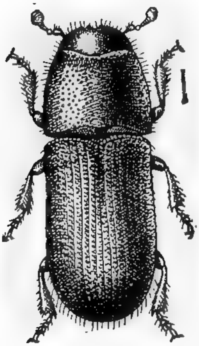

FIG. 33.—The Arizona pine beetle (*Dendroctonus arizonicus*): Adult. Greatly enlarged. (Author's illustration.)

No. 5. THE ARIZONA PINE BEETLE.

(*Dendroctonus arizonicus* Hopk. Figs. 33, 34.)

The Arizona pine beetle (fig. 33) is a somewhat elongate, brown to black beetle, from 4 to 5 mm. long, with broad grooved head, sides of prothorax but slightly narrowed toward the head, finely to rather coarsely punctured, and elytra with slightly coarse rugosities toward the base and declivity, the latter with a few long hairs. (See fig. 34.) It attacks healthy, injured, and felled western yellow pine in central Arizona, and evidently excavates galleries similar to those of the southwestern pine beetle, with which it is usually confused. The larvæ make concealed food burrows in the inner bark, and transform to pupæ and adults in individual cells in the outer bark. Like the other species, its destructive work would be indicated by pitch tubes on the trunk and by the fading yellowish to reddish foliage.

SEASONAL HISTORY.

This species was not recognized as distinct from the southwestern pine beetle until after the principal field observations had been made, and while many specimens were collected they were nearly always associated with the latter in similar galleries; therefore there is somewhat meager evidence on which to base conclusions relating to seasonal history, habits, etc. Apparently, however, its habits are in most respects similar to those of the southwestern pine beetle, although it is distinctly separated by specific characters. It is more nearly related to the southern and smaller Mexican pine beetles than to any other species, and therefore it may be found that it has two generations, and a partial third, annually. It is also probable that under isolation and favorable conditions it may, like the southern pine beetle, become very destructive. (See "Economic features" and "Methods of control" under Nos. 1, 2, and 4.)

BASIS OF INFORMATION.

Data regarding this species were obtained through investigations by the writer at Williams, Ariz., September, 1902, and Flagstaff, Ariz., May, 1904, and by J. L. Webb at Flagstaff and Williams, Ariz., May to September, 1904, and Flagstaff, Ariz., August, 1907. It is represented in the forest-insect collection of the Bureau of Entomology by over 50 specimens.

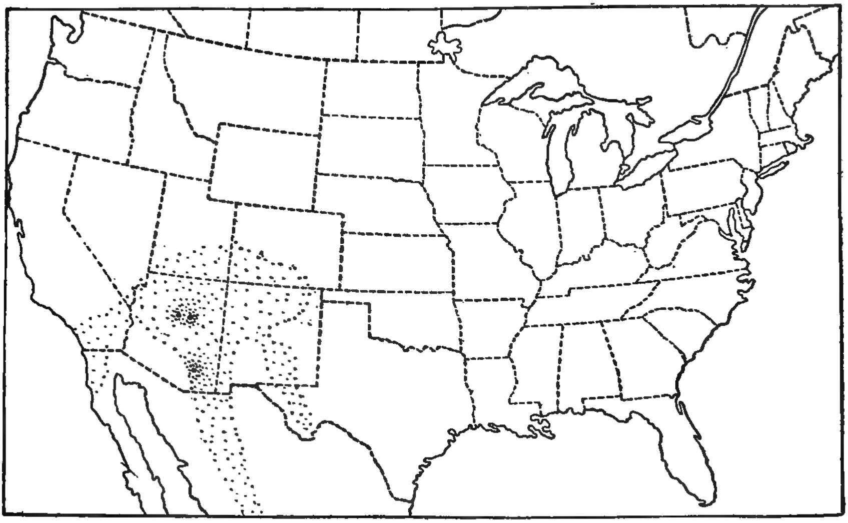

FIG. 34.—The Arizona pine beetle: Distribution map. (Author's illustration.)

This species can be easily distinguished from No. 2, with which it agrees in size, by the long hairs on the declivity of the elytra, and from the smaller examples of No. 8 by the fine punctures of the striæ of the declivity, from No. 3 by the grooved head, and from No. 6, to which it is closely allied, by the distinctly more pubescent pronotum and elytra.

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No. 6. THE SMALLER MEXICAN PINE BEETLE.

(*Dendroctonus mexicanus* Hopk. Figs. 35, 36.)

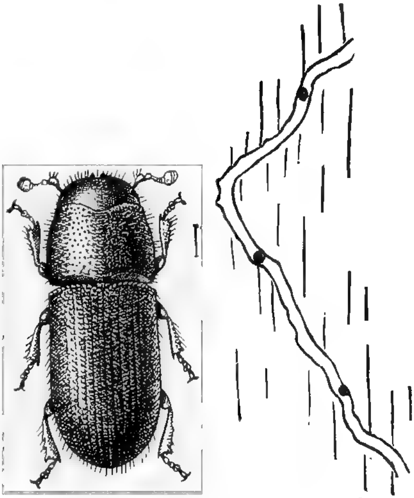

FIG. 35.—The smaller Mexican pine beetle (*Dendroctonus mexicanus*): Adult, greatly enlarged, and section of egg gallery, slightly enlarged. (Author's illustrations.)

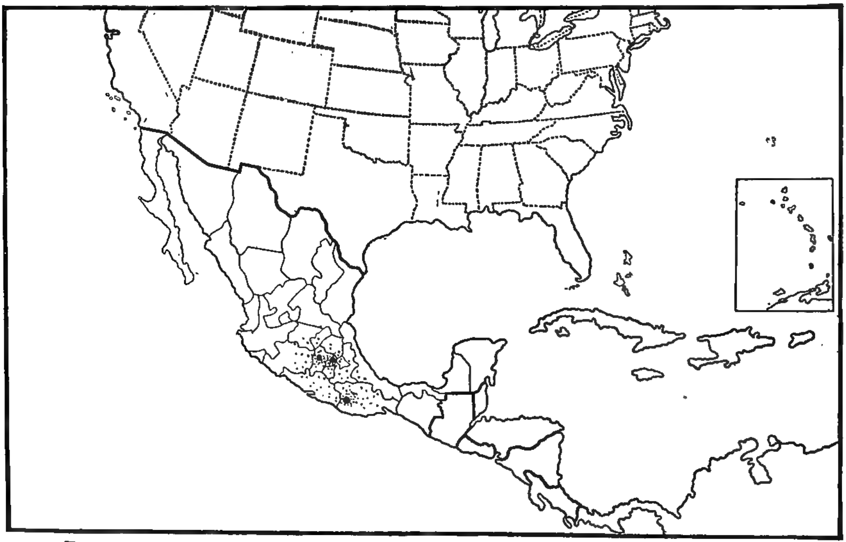

FIG. 36.—The smaller Mexican pine beetle: Distribution map. (Author's illustration.)

The smaller Mexican pine beetle (fig. 35) is a dark brown, elongate, cylindrical barkbeetle, ranging in length from 3 to 4 mm., with head broad and grooved, prothorax but slightly narrowed toward the head, and punctured, and elytra with coarse rugosities toward the base and declivity, the latter with long hairs. It attacks pine trees in Mexico, where a large amount of timber has died in certain localities, evidently owing to the work of this and the larger Mexican pine beetle. It excavates winding egg galleries (fig. 35) through the inner bark, the larval mines being concealed, like those of the western and southwestern pine beetles, beneath the inner surface of the bark. Very little appears to be known of the seasonal history and habits of this species, but evidently they will be quite similar to those of the southwestern, southern, and Arizona pine beetles. It will therefore be subject to the same general treatment for its control, namely, the removal and burning of the infested bark during the principal period of larval development and during the inactive or overwintering periods, if such are found within its range.

This species has not been recognized within the United States, but it is not improbable that it may be found in the pine forests of southern Arizona and New Mexico.

The writer has identified thirty-six specimens received from Prof. A. L. Herrera and Dr. S. J. Bonansea, collected from pine in Amecameca, Michoacan, and Tacubaya, Mexico.

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No. 7. THE LARGER MEXICAN PINE BEETLE.

(*Dendroctonus parallelocollis* Chap. Figs. 37–39.)

The larger Mexican pine beetle is a somewhat elongate, cylindrical, dark brown to black barkbeetle, 5 to 6 mm. in length, with broad, deeply grooved head; broad prothorax, with sides nearly parallel and but slightly narrowed toward the head, and elytra with dense, moderately coarse rugosities, the declivity with coarse punctures and long erect hairs. (See fig. 37.) It attacks living pine trees in Mexico, excavating coarse, slightly winding, longitudinal or oblique and sometimes branched egg galleries (fig. 38) through the inner bark. The larval mines are evidently concealed beneath the inner layers of bark, and the larvæ evidently transform to pupæ in separate cells in the outer bark. It is usually associated with the smaller Mexican pine beetle in the same tree.

Very little appears to be known in regard to the seasonal history of this species, but it is so closely related to the Colorado pine beetle in general characters that it is probably quite similar in seasonal history as well as in habits and in the character of injury to the trees, except in such minor differences as may be brought about by its more southern range. It is evident that the unhealthy and dying condition of the pine in certain localities in Mexico, which has been reported from time to time, is caused largely by this species and by the smaller Mexican pine beetle.

Ten specimens of the beetle and one of the galleries, received from Prof. A. L. Herrera, collected in Michoacan, etc., have been examined and identified by the writer.

If this species is found overlapping the range of the Colorado pine beetle, it can be distinguished from that species by the slightly longer prothorax, with sides more parallel and less narrowed toward the head.

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Hopkins, 1906, pp. 80–81; Hopkins, 1909, pp. 99–101.

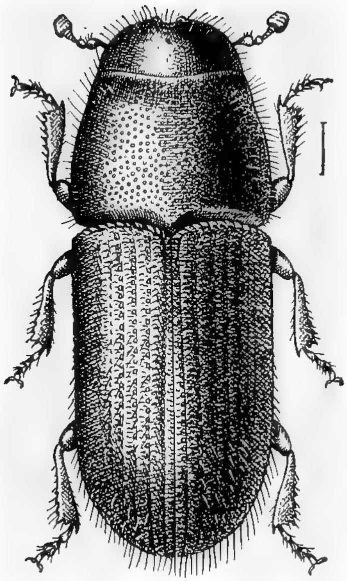

FIG. 37.—The larger Mexican pine beetle (*Dendroctonus parallelocollis*): Adult. Greatly enlarged. (Author's ill.)

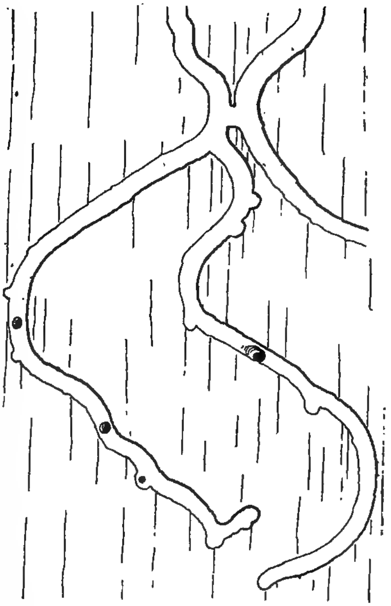

FIG. 38.—The larger Mexican pine beetle: Section of egg gallery. Reduced. (Author's ill.)

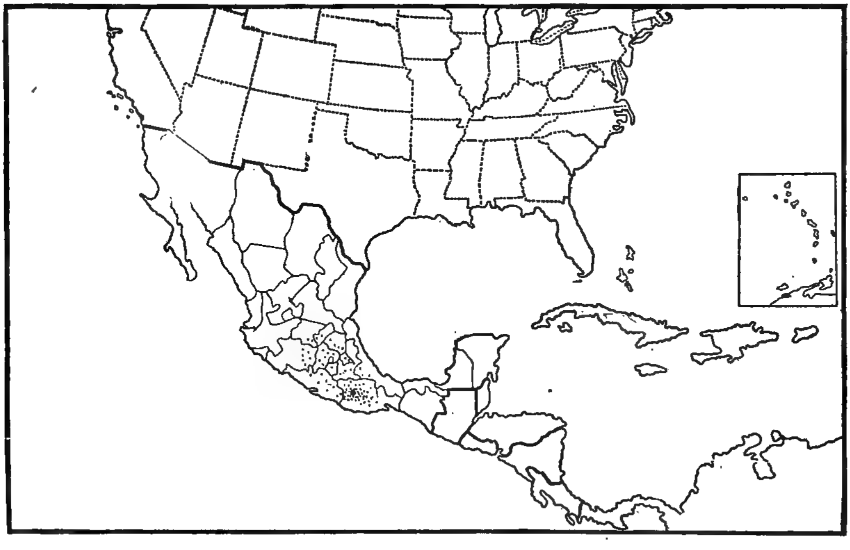

FIG. 39.—The larger Mexican pine beetle: Distribution map. (Author's illustration.)

No. 8. THE COLORADO PINE BEETLE.

(*Dendroctonus approximatus* Dietz. Figs. 40–43.)

The Colorado pine beetle (fig. 40) is a somewhat elongate, cylindrical, dark brown to black barkbeetle, 4 to 7.4 mm. in length, with broad, deeply grooved head; prothorax broad, punctured, and but slightly narrowed toward the head, and elytra with dense, moderately coarse rugosities, the declivity with coarse punctures and long, nearly black, erect hairs. It attacks injured, dying, and healthy western yellow pine, from central Colorado and Utah to southern Arizona and New Mexico. It excavates long, slightly winding, longitudinal and sometimes transverse, and branched egg galleries through the inner living and dying bark, and grooves the surface of the wood (fig. 41); the larval mines are usually concealed beneath the inner bark and the larvæ usually transform to pupæ and adults in the outer bark. It is nearly always associated with one or more of species, 2, 3, 5, and 10 in the same tree.

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed as parent adults, young adults, young to matured larvæ, and possibly pupæ—the parent adults in the egg galleries in the inner bark and the broods in the outer bark of trees attacked the preceding summer.

ACTIVITY OF OVERWINTERED BROODS.

From the beginning of warm weather until in June the overwintered parent adults extend their old galleries and excavate new ones and deposit eggs. The overwintered broods of young adults begin to emerge from the trees early in June and continue to come out until September or later. The overwintered broods of larvæ probably begin their transformation to pupæ and adults in June and continue to do so until September or later. The adults begin to emerge in June, but their principal period of emergence is in July, and they continue to come out until September or later. It is probable that some individuals or broods which pass the winter as young larvæ may be retarded in their development and pass the second winter as matured larvæ or adults.

GENERATION.

The overwintered broods of young adults evidently begin to attack the trees, excavate galleries, and deposit eggs early in June, or earlier in their southern distribution. The principal attack is in June, July, and August, but they continue the attack until September or later. Some of the broods from eggs deposited in June may develop to adults in September, but it appears that they do not emerge and that the majority of the broods of this generation pass the winter as larvæ, young adults, and parent adults.

There is, therefore, but one generation annually, and it is probable that, like the roundheaded pine beetle, some individuals of the same generation may not complete their development until the second year, and that some adults may live over and deposit eggs the third year.

HABITS.

The habits of this species appear to be similar to those of the roundheaded pine beetle, with which it is frequently associated in the same tree. The character of the primary or egg gallery is distinguished by the larger, coarser appearance and by the absence of exposed larval mines on the inner surface of the bark. The character of the primary galleries is shown in figures 41 and 42. It appears that while some of the larvæ may transform to adults in the inner bark, the majority of them transform in separate cells in the outer bark. The flight and food habits of the adults are evidently similar to those of the other species.

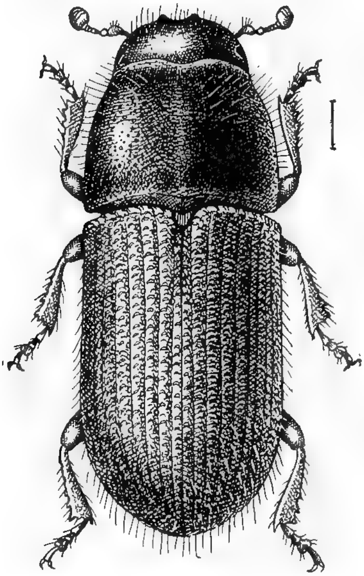

FIG. 40.—The Colorado pine beetle (*Dendroctonus approximatus*): Adult. Greatly enlarged. (Author's illustration.)

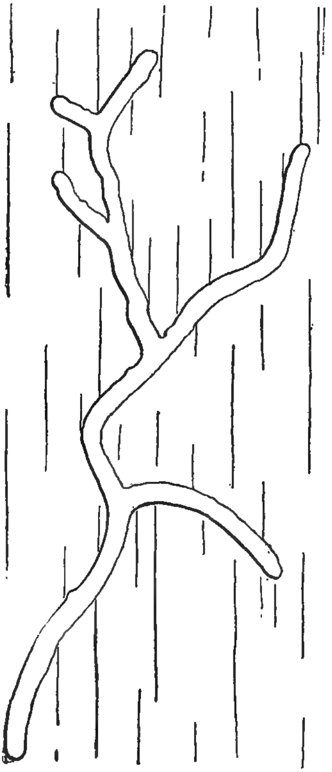

FIG. 41.—The Colorado pine beetle: Single egg gallery. Reduced. (Author's illustration.)

ECONOMIC FEATURES.

This species has been found attacking perfectly healthy trees in sufficient numbers to kill them. Therefore, if it should become isolated, and under favorable conditions multiply rapidly, it might easily become very destructive. As a rule, however, it prefers to breed in injured, dying, and felled trees, in company with one or more of the other species. (See also general discussion under "Character and Extent of Depredations" and "General Methods of Control" (pp. 4 and 29–35), and "Economic Features," etc., for Nos. 1, 2, and 4.

BASIS OF INFORMATION.

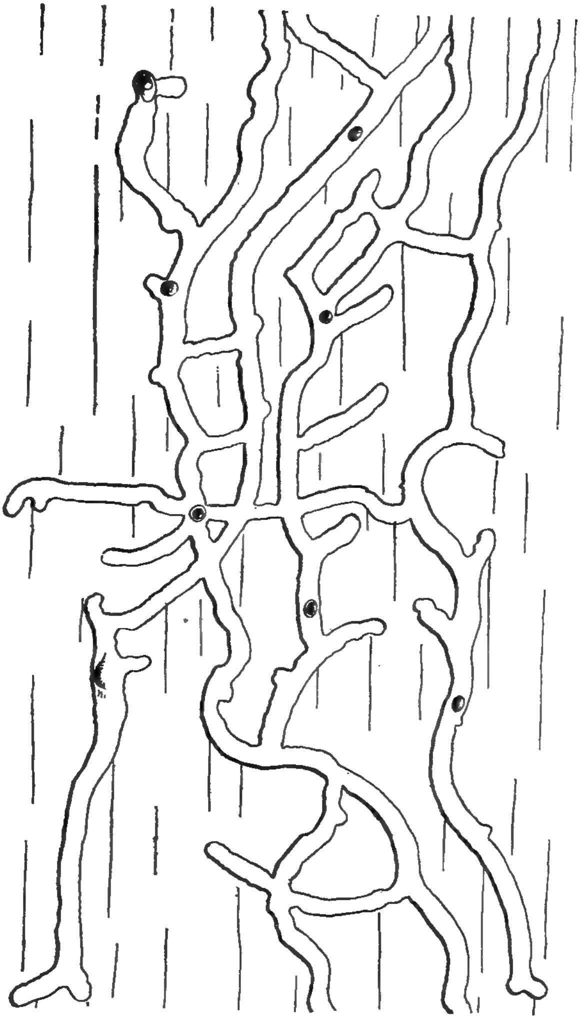

FIG. 42.—The Colorado pine beetle: Egg galleries. Reduced. (Author's illustration.)

Information regarding this bark-beetle is based on investigations by the writer at Williams, Ariz., September, 1902, at Flagstaff, Ariz., in 1904, and at Palmer Lake, Colo., October, 1905; by Mr. J. L. Webb at Flagstaff, Ariz., May to September, 1904, in the Capitan Mountains, and White Mountains, and at Cloudcroft, N. Mex., and in the Santa Catalina National Forest, Rincon Mountains, and Chiricahua National Forest, Arizona, May to September, 1907; by Mr. W. F. Fiske at Capitan, Cloudcroft, and Meeks, N. Mex., March to May, 1907; by Mr. H. E. Burke at Kamas, Panguitch, and Panguitch Lake, Utah, July, 1907; by Mr. W. D. Edmonston at Brookvale, Monte Vista, and Laveta, Colo., in 1907. Additional localities through correspondence and from other collections are the Chiricahua Mountains, New Mexico; Paradise and Show Low, Ariz., and Glenhaven, Colo. It is represented in the forest-insect collection of the Bureau of Entomology by more than 150 specimens.

This species is closely allied to No. 7, of Mexico, and was at one time thought by the writer to be a variety of it,[a] but recent studies indicate that it is a good species, distinguished by the more shining pronotum, more distinctly narrowed and faintly constricted toward the head, the hairs on the sides toward the base slender and less numerous. Therefore it is thought best to retain it as a good species. It is easily distinguished from the other species associated with it in the same region by its elongate form, larger size, and by the deep frontal groove of the head and stiff, erect, blackish hairs on the declivity.

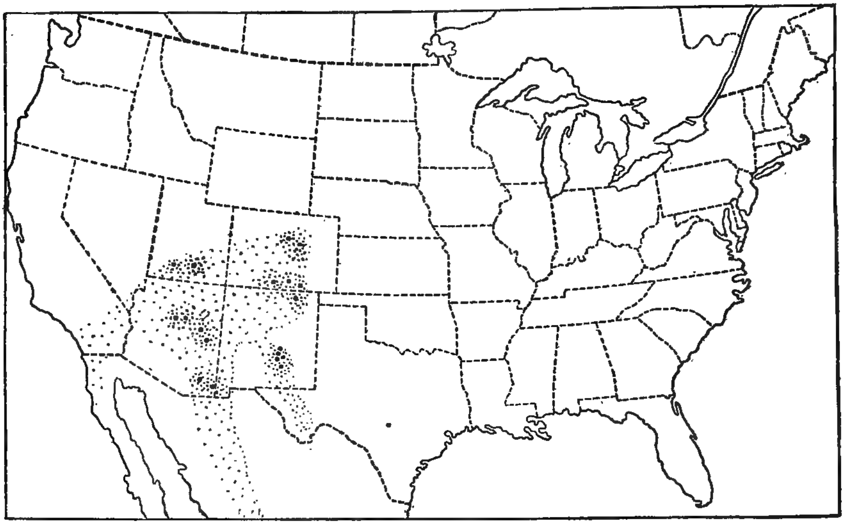

FIG. 43.—The Colorado pine beetle: Distribution map. (Author's illustration.)

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Schwarz, 1902, p. 32; Hopkins, 1903*a*, p. 61; Hopkins, 1904, p. 44; Hopkins, 1905, p. 11; Hopkins, 1906*c*, p. 81; Hopkins, 1909, pp. 101–104.

No. 9. THE MOUNTAIN PINE BEETLE.

(*Dendroctonus monticolæ* Hopk. Figs. 44–50.)

The mountain pine beetle is a stout, black, cylindrical barkbeetle 3.7 to 6.4 mm. long, having the head broad, without frontal groove, but with a short longitudinal impression above the middle; the prothorax short, broad, and punctured, with sides narrowed and slightly constricted toward the head; the elytra with moderately coarse rugosities between rows of punctures, the latter usually indistinct on the sides; the declivity slightly impressed each side of the suture, and with a few long hairs, the striæ narrow, and the spaces between quite broad and roughened with sparsely placed granules. (See fig. 44.) It attacks injured, felled, and healthy silver or western white pine, western yellow pine, and lodgepole pine, in Montana, western Wyoming, Idaho, Oregon, and Washington; it also attacks sugar pine, western yellow pine, and lodgepole pine in the mountains of Washington, Oregon, and California. It excavates very long, nearly straight to slightly, and sometimes strongly, winding egg galleries through the inner living bark and grooves the surface of the wood (figs. 45, 46). The eggs are placed in approximate groups at short intervals along the sides, and the short and broad to long and slender larval mines are exposed in the inner bark; the larvæ transform to pupæ and adults in separate cells, exposed or concealed in the inner bark. This species is sometimes associated with the western pine beetle in the same tree, but usually it works independently and occupies the greater part of the bark on the main trunks. Infested trees are first indicated by pitch tubes and later by the fading yellow to reddish foliage.

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[a] Proc. Ent. Soc. Wash., VII, p. 81.

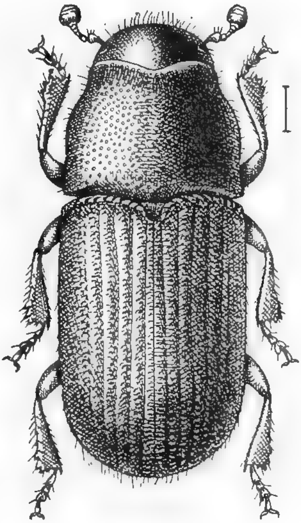

FIG. 44.—The mountain pine beetle (*Dendroctonus monticolæ*): Adult. Greatly enlarged. (Author's illustration.)

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed as larvæ, young adults, and parent adults, in the inner bark of trees attacked the preceding summer and fall, the parent adults in the egg galleries or ventilating burrows, and the broods in the larval mines or pupal cells.

ACTIVITY OF OVERWINTERED BROODS.

As soon as the weather is favorable in April and May the overwintered parent adults extend their incompleted egg galleries or excavate new ones in the remaining living bark on the dying trees and deposit eggs. The overwintered broods of young adults begin to emerge in July. The principal period of emergence is in August, but the retarded broods continue to come out until September, or later. The broods of larvæ begin to transform to pupæ and adults in April and May and continue to do so until September, or later. Some of the larvæ evidently pass the second winter as matured larvæ and adults. The broods from eggs deposited by the overwintered parent adults evidently develop to adults in July and August.

GENERATION.

The overwintered broods of adults begin to attack the trees, excavate galleries, and deposit eggs about the first of August and continue to do so during August and September, until October or later, but the principal period of attack is in August. The larvæ begin to hatch early in August and begin to transform to pupæ and adults in September and October. Under favorable conditions a few adults may emerge late in the fall, but evidently it is the normal habit for the broods of this generation to pass the winter as all stages of larvæ, as adults in pupal cases, and as parent adults, and it is evident that some individuals of the delayed broods do not complete their development until in the fall of the year following and that some of them pass the second winter as parent and young adults. There is, therefore, but one generation annually, with a possible overlapping of the generations of three years during the summer.

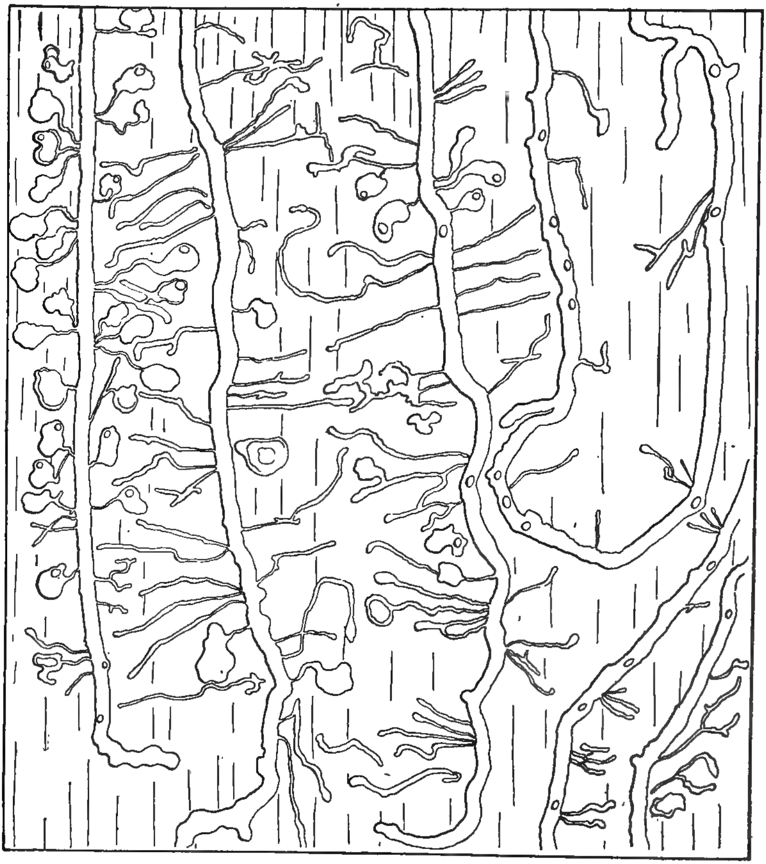

FIG. 45.—The mountain pine beetle: Egg galleries and larval mines in bark. Reduced. (Author's illustration.)

HABITS.

This species apparently prefers to attack injured and felled trees, but is often found attacking healthy living ones. It infests at least four species of pine and one species of spruce, and will doubtless be found in other species of pine and spruce growing within its range.

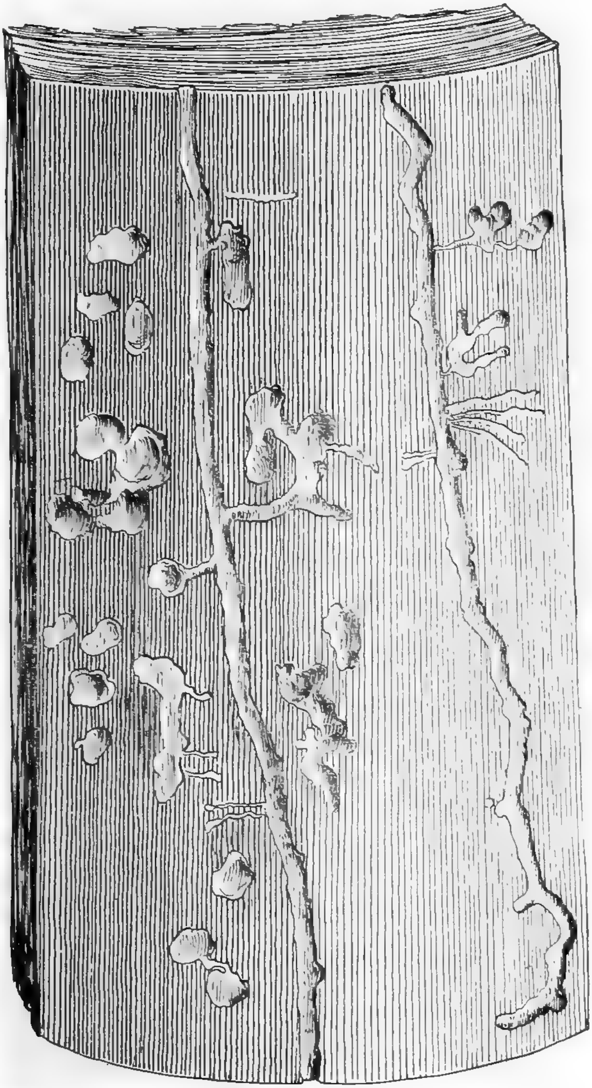

FIG. 46.—The mountain pine beetle: Egg galleries and larval mines grooved in surface of wood. (Author's illustration.)

The parent adults excavate their long, nearly straight, or winding, longitudinal galleries through the living inner bark, and groove the surface of the wood of the main trunk. The larvæ excavate short and broad, or long and slender food burrows at right angles to the primary gallery, and usually transform in their individual pupal cells exposed in the inner bark or between the inner bark and wood, the cells marking the surface of the wood. After the new broods of adults become matured, they often bore out the bark intervening between the cells and congregate under the loose bark before they begin to emerge; some of them, however, bore directly out from the transformation cells.

Scarcely anything is known of the flight habits, but this species evidently flies in swarms late in the evening or at night. It is not improbable, however, that, like its near relative, the Black Hills beetle, it may at times swarm during the day.

ECONOMIC FEATURES.

While this species apparently prefers to attack injured and felled trees, it is in some localities often found attacking and killing the living timber over considerable areas. As a rule, the largest and best trees are attacked first, and their egg galleries and larval mines completely girdle the trunks from near the ground up to the middle branches.

The silver pine or western white pine (fig. 47) and lodgepole pine in Idaho and Montana, the sugar pine (figs. 48, 49) in Oregon and California, and especially the lodgepole pine in the Yosemite National Park, and in northwestern Oregon have suffered severely from its ravages.

EVIDENCES OF ATTACK.

The first external evidence of attack on living timber is the presence of pitch tubes on the outer bark of the trunk or of reddish borings lodged in the flaky bark and around the base of the trees with normal green foliage.

The second important external evidence of attack, and of infested trees, is the fading of the foliage in the fall and spring, followed by a yellowish or sorrel-top condition in May to June, and by red-tops during the period from July to September. The internal evidence is found by cutting into the bark and revealing the characteristic galleries occupied by the broods, but positive evidence of attack or infestation by this species is determined only by authentic identification of specimens taken from the bark. Trees attacked for the first time early in August may have the foliage fading late in the fall, but as a rule the foliage remains green until the following spring. The broods begin to emerge by the time the leaves begin to change to the red-top condition, and are all out by the time all of the leaves are dead and red. Exceptions to this rule are frequently found, where only the top or one side of a tree was killed the first year, or when living bark remains toward the base, which is attacked the second year by the overwintered parent adults and young adults from the overwintered broods. But it is safe to conclude that after the leaves are all dead and brown, very few representatives of the broods will be found in the bark.

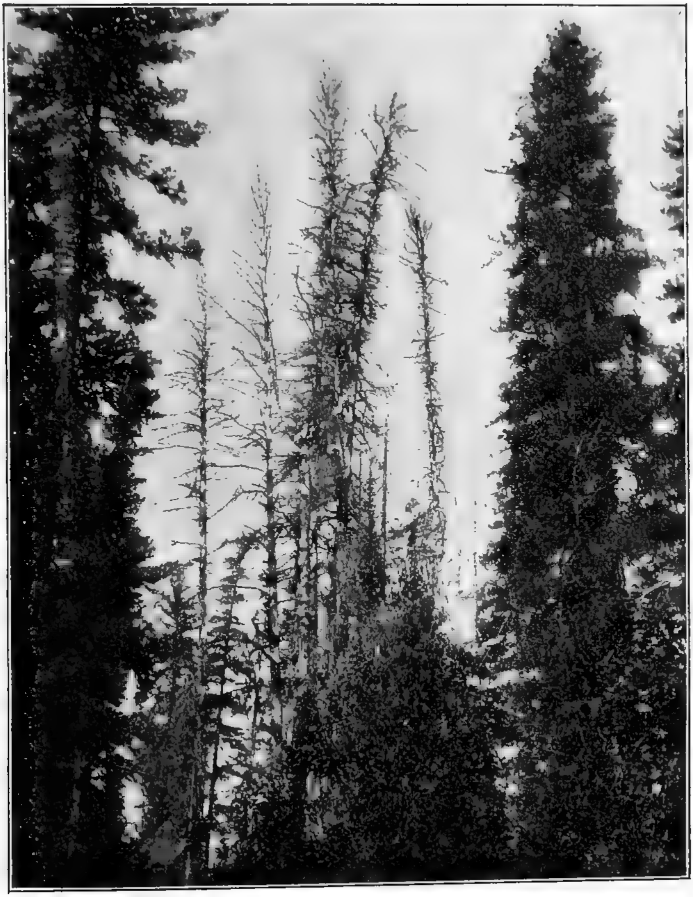

FIG. 47.—Silver or western white pine killed by the mountain pine beetle in the Priest River National Forest, Idaho. (Original.)

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

The commercial value of the silver pine, sugar pine, and lodgepole pine, owing to the thin sapwood, is often not seriously impaired for many years after the trees die, provided they are not injured by fire, storms, wood-boring grubs, and premature decay. The yellow pine, with its thick sapwood, suffers immediate deterioration owing to the bluing fungus which follows the attack of the beetles, causing the wood to blue long before the leaves begin to fade. Except for the secondary injuries by wood-boring insects, fire, etc., the heartwood of the larger trees will remain sound and valuable for several years. While, however, there may not be a very great loss from leaving the dead timber standing until the heartwood begins to deteriorate, the danger of destruction by forest fires is so great that, in order to insure against complete loss, the attacked and infested timber should be felled and utilized before the broods of the beetle develop and emerge, or within two or three years.

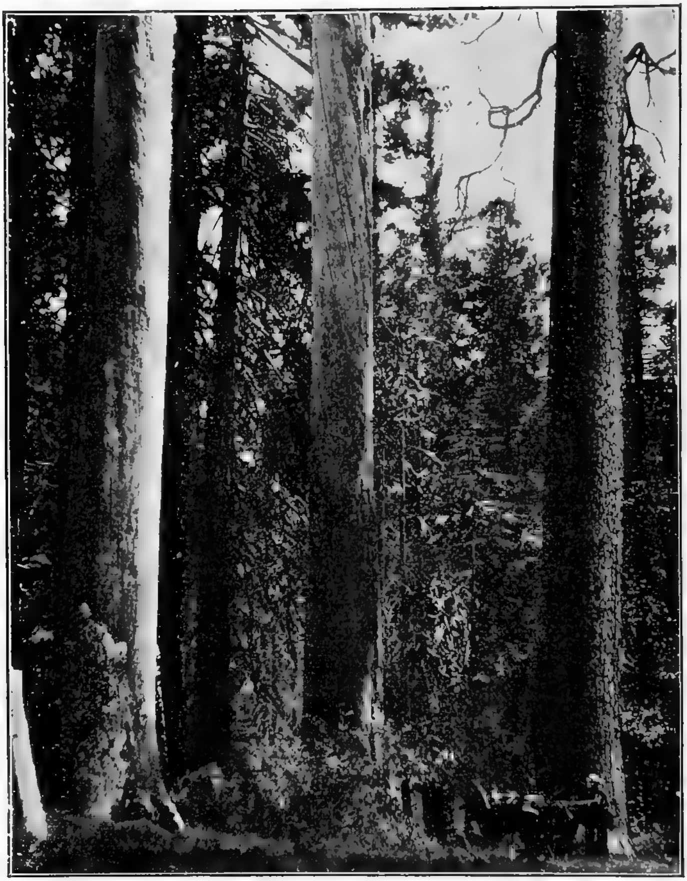

FIG. 48.—Two giant sugar-pine trees killed by the mountain pine beetle, and one dying from recent attack, Yosemite National Park, Cal. Note horse and man by dying tree, indicating diameter of tree at base. Approximate diameter, 8 feet. (Original.)

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication and destructive work of this insect are found in so-called primitive forests with a predominance of mature timber, and where trees are frequently struck by lightning, broken, or felled by storms, landslides, etc., or injured by fire. Unfavorable conditions for attacks on living timber will be found in areas of vigorous young to matured growth under some system of forest management which provides for the utilization of the old timber and especially that injured by storm, lightning, fire, etc.

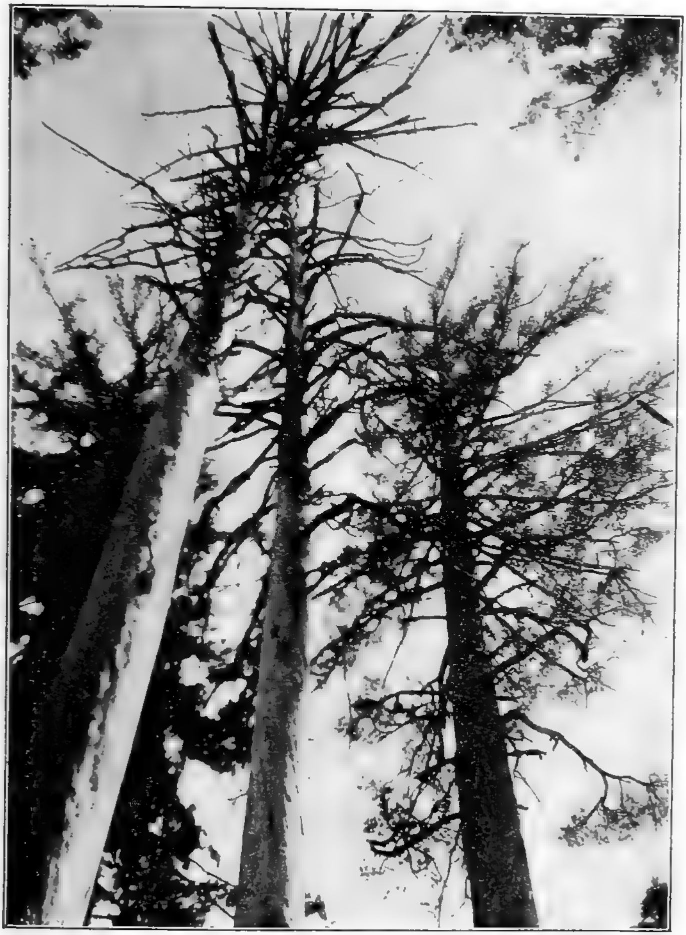

FIG. 49.—The mountain pine beetle: Tops of the trees shown in figure 48. (Original.)

METHODS OF CONTROL.

Whenever it is positively determined that this species is killing the timber and that the bark of living or dying trees contains living broods, the principal groups of infested trees should be located and marked during September, and then during the period beginning in October and ending in the following July the infested bark should be removed from the main trunk. The simple removal of the bark, without burning, is sufficient to kill the broods of this species. If large numbers of lightning-struck trees, and those injured by storms or otherwise, become infested during the summer, they should be barked before the succeeding July. The felling and barking of newly-attacked trees during August and September is not to be recommended for this species.

This species, unlike *D. ponderosæ*, is attracted to injured and felled trees, and therefore may be trapped to a limited extent in trees felled during July and August, and may be destroyed by removing the bark any time between October and the following July. This may or may not provide sufficient breeding places in the felled trees and stumps to prevent attacks on living timber.

Whenever it is necessary or desirable to destroy the broods of this insect in the logs, stumps, and tops, the timber sales or timber-cutting regulations relating to living timber should require that if the slash from winter, spring, and summer cutting is to be burned it should be done during the succeeding fall, winter or spring, and that the work be completed before the first of the succeeding July. Summer burning, to destroy the broods of this species, is undesirable and entirely unnecessary if it can be done later.

The regulations relating to infested timber should require that the first work be directed either to removing the infested bark from the main trunks of the standing trees or to felling and barking the trees, or to utilizing the timber and burning the slabs, so that this essential part of the work may be completed within the specified time, after which the logging operations, including the disposal of the barked and old dead timber, or of the living timber, if the last is included in the sale, may be prosecuted until it is time to begin the barking operations the following October, on any new infestation which may appear within the area covered by the sales.

The lodgepole pine, with its very thin bark, offers more favorable conditions for combating this enemy than the thick-barked western yellow pine and sugar pine. While the parent adults may attack the thinner bark on the upper portion of the trunk and on smaller trees, it is only in the thicker bark on the lower portion of the trunk of the medium to larger trees that the broods will reach their best development. Therefore, while many trees may be killed by the beetles, the removal of the infested bark from the lower portion of the trunks of a comparatively few of them may be all that is necessary, and since this bark can be removed from the standing timber the work need not be expensive. In fact, it may be desirable and more practical to give the infested trees to anyone who will bark them within the specified time.

Whenever the infested timber is in the vicinity of streams or lakes the insects may be destroyed by placing the unbarked logs in the water. Scorching the bark or burning the timber outright, or utilizing it and burning the slabs, may answer the same purpose. It is quite evident that if the infested lodgepole pine be cut in the period from September to February, and the trunks, logs, or trees with infested bark on them crib-piled in the open, the bark will dry sufficiently to kill the broods before they can develop and emerge. Hacking or scoring the bark on the upper side of the logs or felled trunks of the silver pine or sugar pine during December, to let the water in, would doubtless kill the majority of the broods before the time for them to emerge. These suggestions relating to methods of treating unbarked timber should be tried by the foresters and lumbermen and the practical results reported, as should all practical results from the adoption of our recommendations. Failures, as well as successes, should be reported.

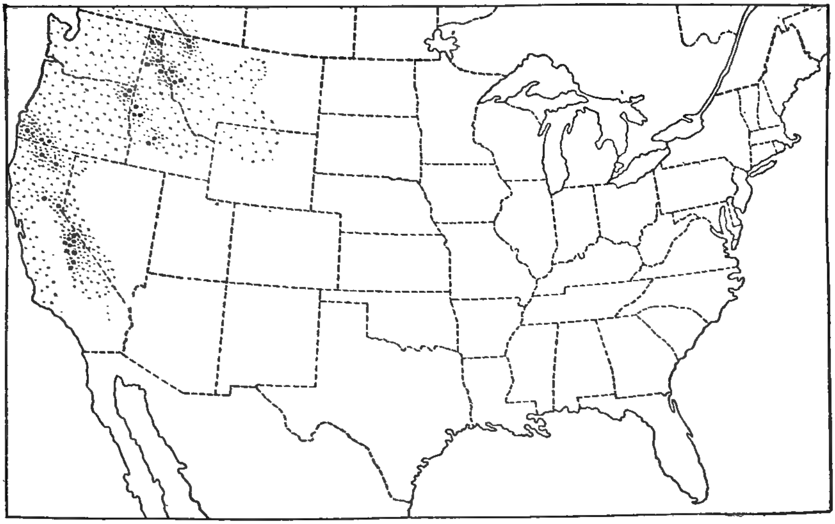

FIG. 50.—The mountain pine beetle: Distribution map. (Author's illustration.)

BASIS OF INFORMATION.

Information concerning this species is based on studies by the writer at Grants Pass, Oregon, and Sand Point and Kootenai, Idaho, in 1899; at Priest River, Idaho, in 1902, and in the Yosemite National Park and Yosemite Valley, California, June, 1904; by Mr. J. L. Webb, at Moscow, Idaho, in 1900; at Centerville, Smith's Ferry, and Collins, and in Boise County, Idaho, June to September, 1905; by Mr. H. E. Burke, at Smith's Ferry, Idaho, October, 1904; at Longmires Springs, Wash., September, 1905; at Wawona, Summerdale, Little Yosemite, Yosemite, Lake Tenaya, Tioga Road, and Soda Springs, Cal., May to September, 1906, and at Joseph, Oregon, and in the Wallowa National Forest, August, 1907. Additional localities, from other collections and through correspondence, are Piedmont and Keystone, Wyo.; Pokegama, Ashland, and Washington National Forest (Portland), Oregon; Columbia Falls, Lewis and Clarke National Forest, Saltese, Missoula, Medicine Bow National Forest, Lolo National Forest (Iron Mountain), and Big Four, Mont.; Coeur d'Alene National Forest and Weiser National Forest, Idaho. It is represented in the forest-insect collection of the Bureau of Entomology by more than 500 specimens, including all stages and work.

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Hopkins, 1899*b* (under *Dendroctonus* n. sp.), pp. 15, 26; Hopkins, 1901*b*, p. 67; Hopkins, 1902*c*, p. 21; Hopkins, 1903*a*, pp. 59–60; Hopkins, 1904 (under "mountain pine Dendroctonus"), pp. 19, 42, 45; Hopkins, 1905, p. 1; Webb, 1906, p. 22; Hopkins, 1909, pp. 105–109.

No. 10. THE BLACK HILLS BEETLE.

(*Dendroctonus ponderosæ* Hopk. Figs. 51–59.)

The Black Hills beetle is a stout, black, cylindrical barkbeetle, 4 to 7 mm. in length, with head broad and without frontal groove, but with slight longitudinal impression above or behind the middle; the prothorax short, broad, and punctured, the sides narrowed and slightly constricted toward the head; the elytra with moderately coarse rugosities between the rows of punctures, which are usually distinct on the sides, and the declivity, which bears a few long hairs, slightly impressed each side of the middle line, the impressed striæ narrow, and the interspaces broad and roughened with sparsely placed, coarse granules. (See fig. 51.) The adult beetles attack living and sometimes injured and felled, yellow pine, lodgepole pine, limber pine, Mexican white pine, white spruce, and Engelmann spruce from the Black Hills, South Dakota, to southern Arizona, and westward into Utah, and are very destructive. The parent beetles excavate long, nearly straight, longitudinal egg galleries (fig. 52) through the inner living bark and groove the surface of the wood on the main trunk (figs. 53, 54). The eggs are placed at quite regular intervals, or more often arranged in groups of four or five along the sides. The short, broad larval mines and transformation cells are exposed in the inner bark and mark the surface of the wood; the short, whitish, grublike larvæ (fig. 51) transform to pupæ (fig. 51), usually exposed in the inner bark, and the broods usually work independently of other species and occupy exclusively the greater part of the bark on the main trunks of the trees. The attack causes pitch tubes (figs. 55, 56) on the trunk of the infested trees in the summer and fall, and the leaves fade and turn yellow and red the following season during the period from May to August.

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed in the inner bark on trees attacked the preceding summer and fall, as parent adults in the egg galleries, all stages of larvæ in the larval mines and transformation cells, and as broods of young adults in transformation cells; but principally as larvæ.

ACTIVITY OF OVERWINTERED BROODS.

As soon as warm weather begins in April and May the overwintered parent adults extend their incompleted egg galleries and excavate new ones in the remaining living bark on the dying trees and deposit eggs. The overwintered broods of young adults begin to emerge from the trees by the middle of July, but the main swarm does not appear until the last of July and first of August. Some of the retarded broods continue to come out until October, or later. The broods of larvæ begin to transform to pupæ and adults about the middle of May, and continue to do so during the period from June until September, or later, and begin to emerge in August.

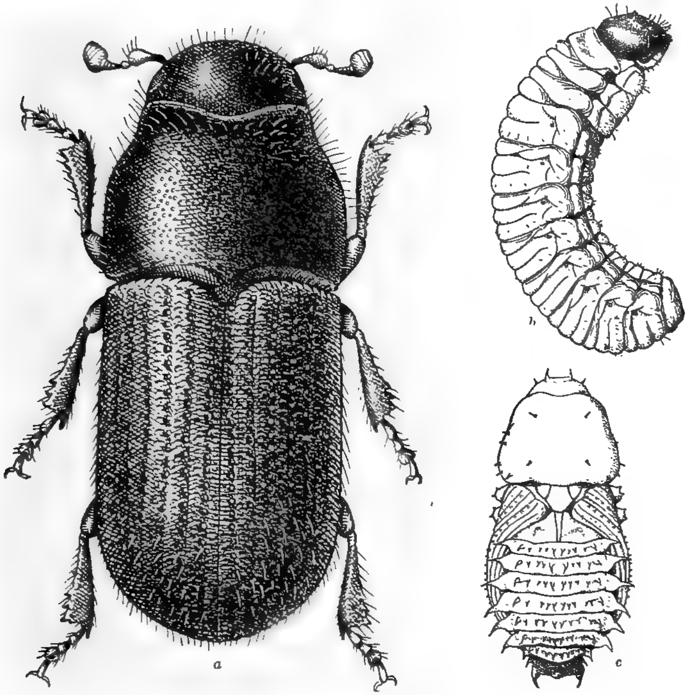


FIG. 51.—The Black Hills beetle (*Dendroctonus ponderosæ*): *a*, Adult; *b*, larva; *c*, pupa. *a*, Greatly enlarged; *b*, *c*, less enlarged. (Author's illustrations.)

The broods from eggs deposited by the overwintered parent adults may develop to adults in August and September, but evidently remain in the bark until the next season of activity.

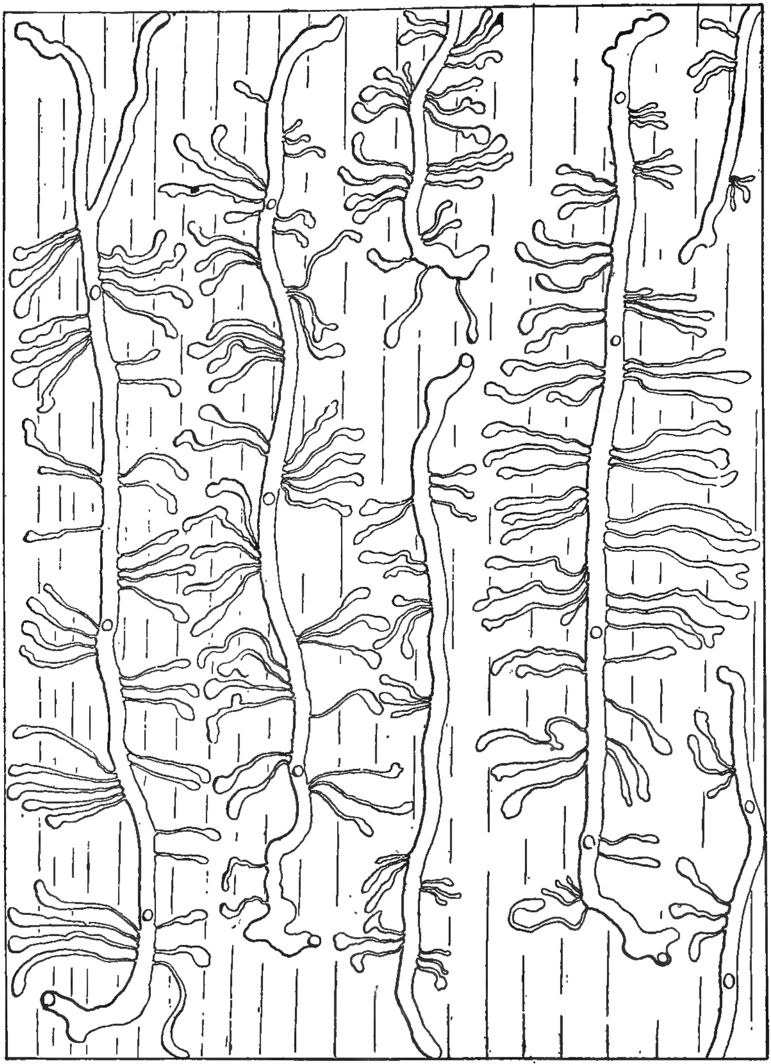


FIG. 52.—The Black Hills beetle: Egg galleries and larval mines. Slightly reduced. (Author's illustration.)

GENERATION.

The overwintered broods of young adults begin to attack the trees, excavate galleries, and deposit eggs toward the last of July; the principal attack is during August, but continues during September and until October, or possibly later. The eggs hatch and the larvæ begin to feed about the first of August. The principal activity of the larvæ is during the latter part of August, but they continue active until the beginning of hibernation in the fall. The larvæ of a few of the most advanced broods may begin to transform to pupæ and adults toward the last of September and in October, but by far the greater number overwinters in different stages of larvæ with the parent adults. There is, therefore, but one generation each year. It is evident, however, that some retarded individuals from the preceding generation may pass the second winter as young and parent adults. Thus, during the early summer there may be an overlapping of representatives of two and even three annual generations.

HABITS.

This species apparently prefers to attack living timber, but will breed to a very limited extent in injured and felled trees. It infests at least four species of pine and two species of spruce, and will doubtless attack other pines and spruces (except the "Douglas spruce") growing within its range. It prefers the western yellow pine, or bull pine. The largest and best trees are usually attacked first, but after these are killed it will attack and kill the medium to small trees and even saplings 8 or 10 feet high or only a few inches in diameter.

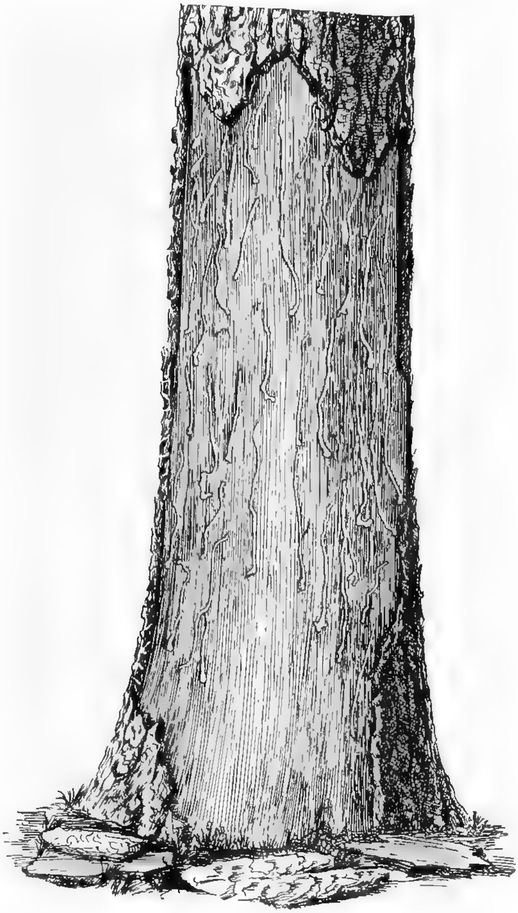


FIG. 53.—The Black Hills beetle: Tree with bark removed, showing egg galleries grooved and marked on surface of wood. (Author's illustration.)

The parent adults excavate their long, nearly straight, longitudinal egg galleries in great numbers through the inner bark, where they often closely parallel each other. The larvæ excavate short and broad or long food burrows at right or oblique angles to the egg galleries through the intervening bark, and transform to pupæ and adults in individual cells at the farther end or toward the middle of their larval mines, which are exposed in the inner bark when it is removed from the tree. Both the egg galleries and larval mines cause marks and grooves on the surface of the wood. After the new broods of adults become matured, they burrow through the intervening bark between their cells, and congregate in the general cavity thus formed, until the proper time for them to emerge, when they all come out and fly in swarms to attack the remaining living timber.

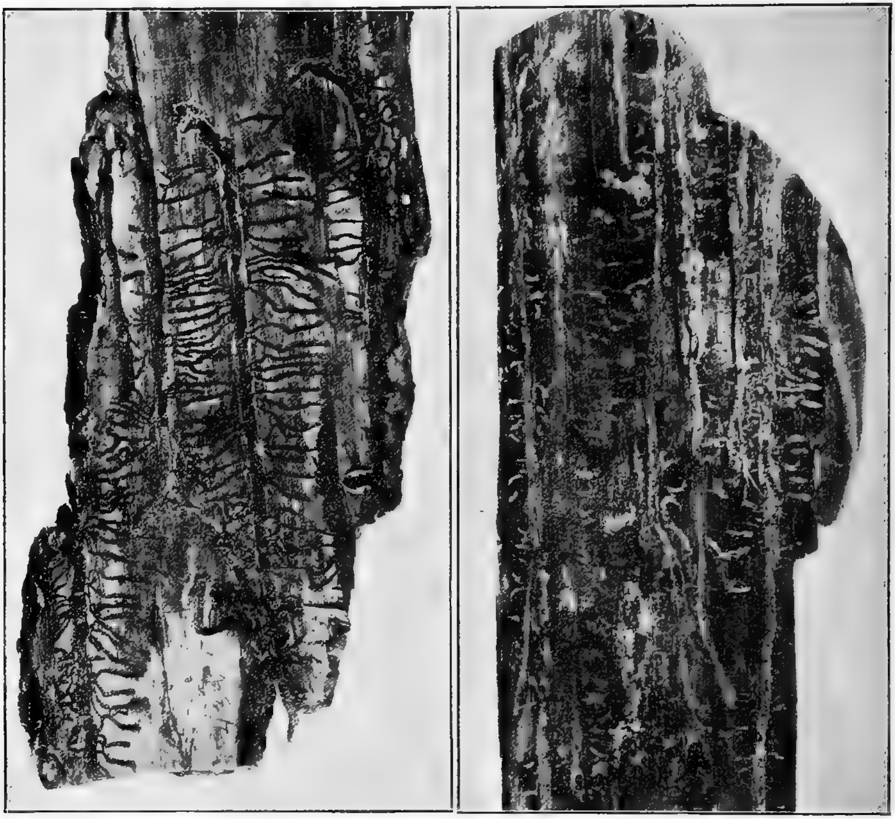


FIG. 54.—The Black Hills beetle: Galleries in bark and marked on scoring chip. About one-third natural size. (Author's illustration.)

Sufficient information relating to the flight of this species has been secured to indicate quite conclusively that it flies in swarms during the day, and probably at night.

ECONOMIC FEATURES.

This species apparently differs from all of the others in its decided preference for living timber, in which it excavates its egg galleries in such a manner as to kill the tree and make the conditions favorable for the development of its broods. It is, therefore, a primary enemy of the first importance, especially as related to the western yellow pine in the eastern section of the Rocky Mountain region south of eastern Montana. It has destroyed a vast amount of the best timber in the Black Hills National Forest of South Dakota, and is threatening the destruction of practically all of the best timber there, as well as much of the reproduction. It is also destructive to the pine in Colorado, New Mexico, and Arizona. There is evidence that extensive forests have been destroyed in Colorado by this beetle and by resulting forest fires during the past fifty or seventy-five years.

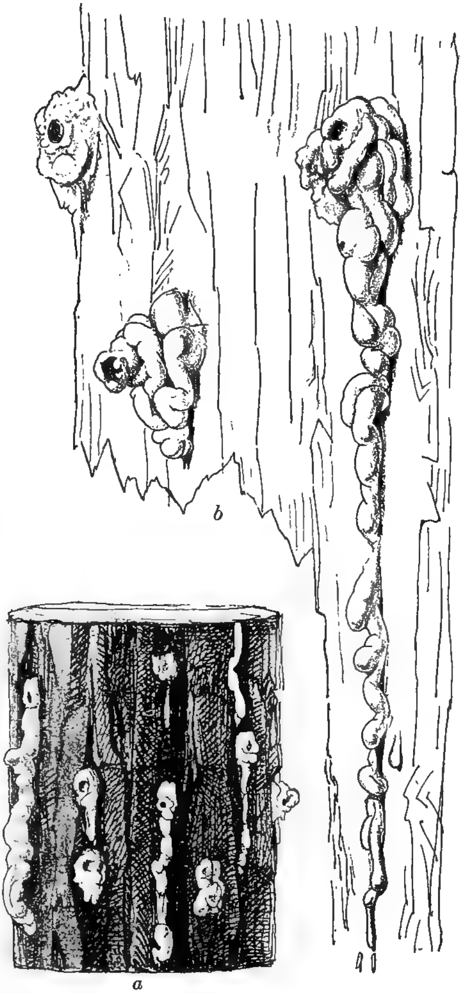
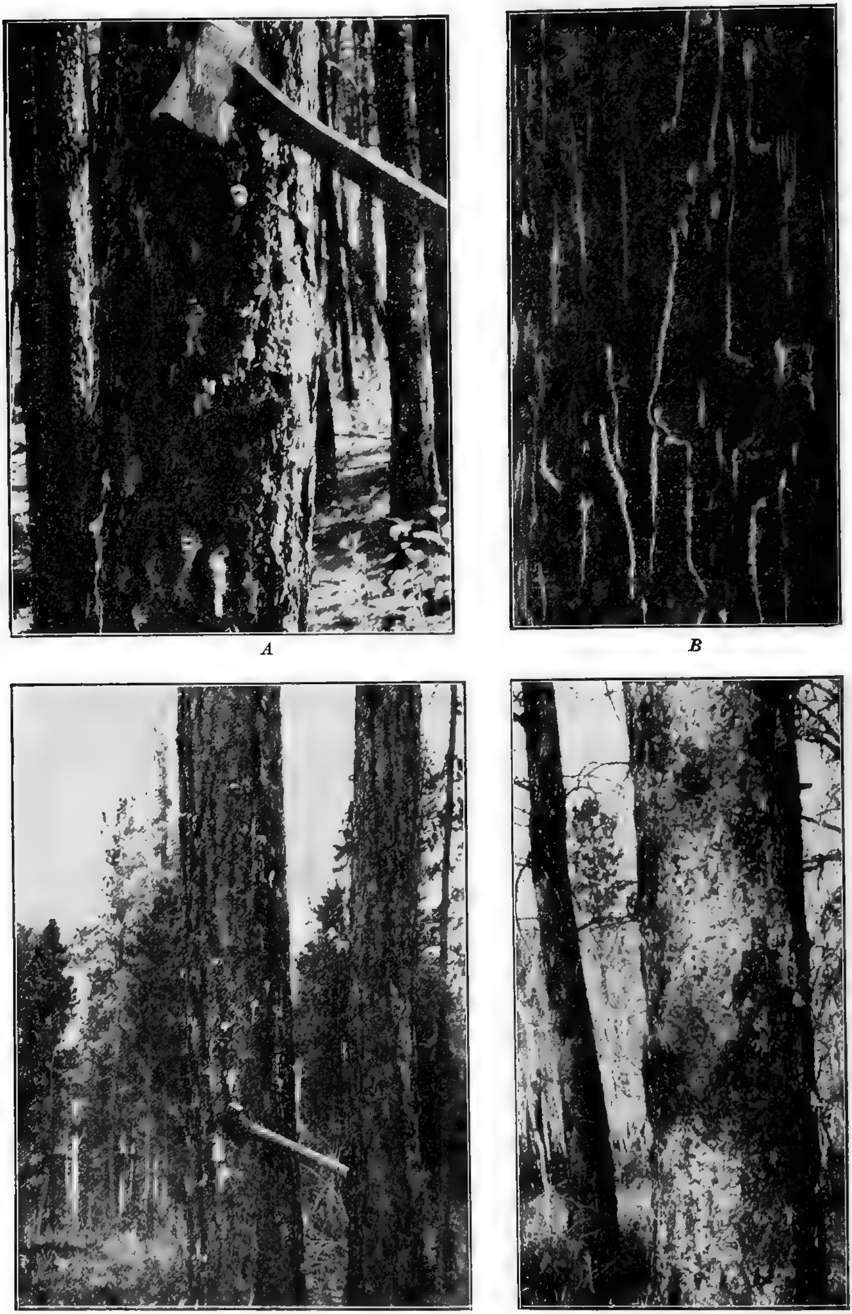


FIG. 55.—The Black Hills beetle: *a*, Pitch tubes on surface of bark, reduced; *b*, same, two-thirds natural size. (Author's illustration.)

EVIDENCES OF ATTACK.

The first evidence of attack and infestation on living timber is the appearance of pitch tubes on the bark of the main trunk, or, in the absence of these, of reddish borings lodged in the loose bark and on the ground around the base of the trees. This is usually the only external evidence from the time the trees are attacked in the summer and fall until the following spring. Sometimes during the winter, and especially in the period from April to June, the more noticeable evi-



A

B

C

D

FIG. 56.—Work of the Black Hills beetle in the Black Hills National Forest: *A*, Small freshly attacked fine tree, showing pitch tubes. *B*, Marks of primary galleries on surface of wood when bark is removed. *C*, Freshly attacked tree, showing pitch tubes; near tree not attacked. *D*, Dead tree, showing where outer bark has been removed by woodpeckers. (Author's illustration.)

dence is found in the fading foliage which begins to change to sorrel tops in May and June and to red tops in July and August. The finding of these conditions within the region occupied by this species will indicate destructive work by barkbeetles, but positive evidence of the presence of this species can only be determined by cutting into the bark and finding the characteristic galleries and mines occupied by authentically identified beetles. As a rule, the broods have left the trees by the time the leaves are all dead, and sometimes before the leaves have changed from yellow or sorrel to red. Exceptions are frequently found when but one side or the top of a tree is killed the first year and the remaining living bark is infested with broods of the next. It is safe to conclude, however, that after the leaves are all dead and brown, very few living examples of this species will remain in the bark.

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

Owing to the thick sapwood of the western yellow pine, the commercial value is reduced for certain purposes by a bluing condition, which affects it soon after the trees are infested by the beetles in August and September and long before the leaves begin to fade. The heartwood of large trees is not usually reduced in value for several years after the trees die, provided they do not suffer from subsequent injury by storm, fire, wood-boring insects, or premature decay. If left standing, however, with the bark on, until the branches and tops begin to fall, the loss from decay may be complete. On the other hand, if the bark be removed from the trunks of the standing trees, the heartwood will remain sound for many years longer.

The danger, however, of the total destruction of the dead timber by forest fires is so great that in order to insure against such losses, and at the same time destroy the broods of insects, the insect-killed timber should be utilized before the insects emerge.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication and destructive work of this species are found in somewhat isolated forests with a predominance of large mature timber. Unfavorable conditions for destructive outbreaks will be found in forests, isolated or not, which are kept under a system of forest management or regulations which provide for the utilization of the mature timber and the barking of trees injured by lightning or dying from any cause, before the broods of insects develop in the bark and emerge.

METHODS OF CONTROL.

Whenever it is positively determined that this species is attacking living pine timber in a given locality and that the bark of living and dying trees contains living parent adults or developing broods, active and radical measures should be promptly adopted for its control.

The simple removal of the infested bark from the main trunks of the trees, without burning it, is sufficient to kill the broods of this species, provided the work be done between the first of October and the first of June. If, in the case of a moderate outbreak, the larger clumps or patches of infested trees and the more accessible scattering ones in the worst affected sections of a forest are thus treated, it should serve to bring the pest under control the first year, but in the case of a very extensive outbreak this may require two or three years or more.

If all of the infested trees can be barked or utilized and the slabs burned without much additional expense, it may be best to do so, but where, for any reason, this can not be done within the specified time, the work should be planned so as to insure the barking or utilization of all of those in the larger patches, or an aggregate of 75 per cent of the infested trees to each square mile.

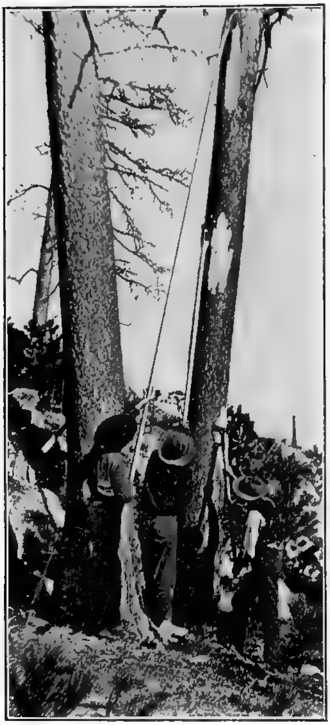


FIG. 57.—Removing bark from trunk of standing tree with special barking tool having handles of different lengths, to destroy broods of the Black Hills beetle. (Original.)

If the bark be removed from the standing trees (figs. 57, 58), an aggregate of 75 per cent or more of the actually infested bark should be removed from all of the trees, or all of the infested bark should be removed from 75 per cent of the trees. *The work should be planned and conducted with the object of destroying the greatest possible number of insects for the labor and time expended.* That is, if there are more infested trees than can be barked within the specified time, and five or six times as many insects can be killed by removing half of the infested bark from the standing trees as can be done in the same time by felling one tree and removing all of the bark, the former is far preferable, remembering that it is not necessary to exterminate the enemy, but that it is necessary to reduce its numbers beyond the power of doing harm.

The removal of the infested bark from at least the lower half of the standing trees offers many advantages over felling the trees for the purpose of barking all of the trunk. More insects can be destroyed in the standing trees within a given time and the barked standing timber may be left standing until suitable facilities can be provided for its utilization; thus, if necessary, all of the specified time for the destruction of the insects may be devoted exclusively to the removal of the bark.

The barking of newly attacked trees in August and September is not to be recommended for this species. Trap trees are of little or no service in combating it and continued timber-cutting operations appear to have little or no influence in checking its ravages on living timber.

Recent reports of conditions in the vicinity of Colorado Springs, where a large percentage of the infested timber was barked in 1905 and during the winter and spring of 1906, indicate most successful and satisfactory results. (See also other references to successful control, pp. 36–38.)

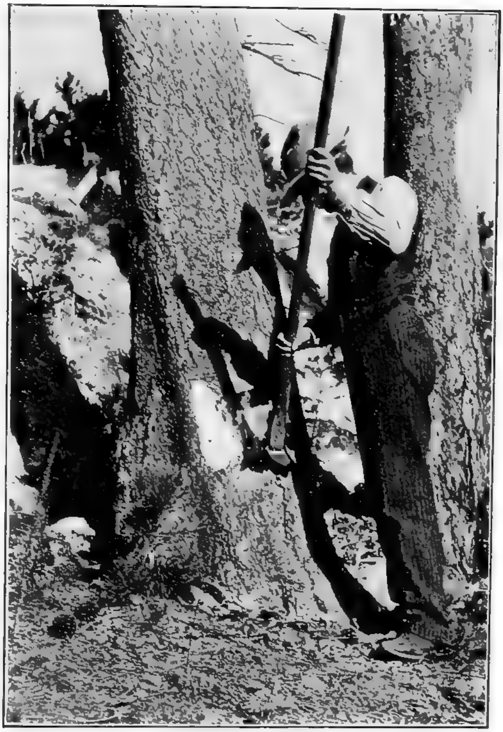


FIG. 58.—Removing bark from base of trunk of standing tree with special barking tool, to destroy broods of the Black Hills beetle. (Original.)

The depredations in the Black Hills have been so extensive that little or nothing has been accomplished toward the control of the beetle, owing to lack of sufficient funds and other facilities for adopting the radical measures necessary to accomplish anything of importance.

(For additional information, see Bulletin No. 56, Bureau of Entomology, of which the above is a partial revision.)

BASIS OF INFORMATION.

The data on this barkbeetle have been secured through investigations by the writer in the Black Hills National Forest, September, 1901, August, 1902, and June, 1903; at Vermejo, N. Mex., May, 1903; at Flagstaff, Ariz., May, 1904; in the Pike National Forest and in the vicinity of Colorado Springs, Colo., October, 1905, and June, 1906, and in the vicinity of Fort Garland, Colo., June, 1906; by Mr. J. L. Webb, in the Black Hills National Forest, South Dakota, May to October, 1902, and April to September, 1906; in the Chiricahua National Forest, Arizona, June to September, 1907; by Mr. H. E. Burke, at Nemo, S. Dak., November, 1904; at Kamas, Panguitch, and Panguitch Lake, Utah, June to September, 1907; by Mr. W. D. Edmonston, at Larkspur, Colo., July, 1906; at Brookvale, Sequache, Poncha Springs, San Juan National Forest, Wagon Wheel Gap, Cochetopa National Forest, Monte Vista, White River National Forest, Uncompahgre National Forest, and Colorado Springs, Colo., January to December, 1907; in the San Isabel National Forest, at Hahns Peak and Clarke, in the Gunnison National Forest, the Hayden National Forest, the La Salle National Forest, the Ouray National Forest, the Pike National Forest, the Routt National Forest, the San Juan National Forest, the Wet Mountains National Forest, and the White River National Forest, Colorado (12 national forests), and at Encampment and Downington, Wyo., in 1908. Additional localities through correspondence and other collections are Palmer Lake, Cat Mountain, Trinchera Estate, Fort Collins, Pine, and the Medicine Bow National

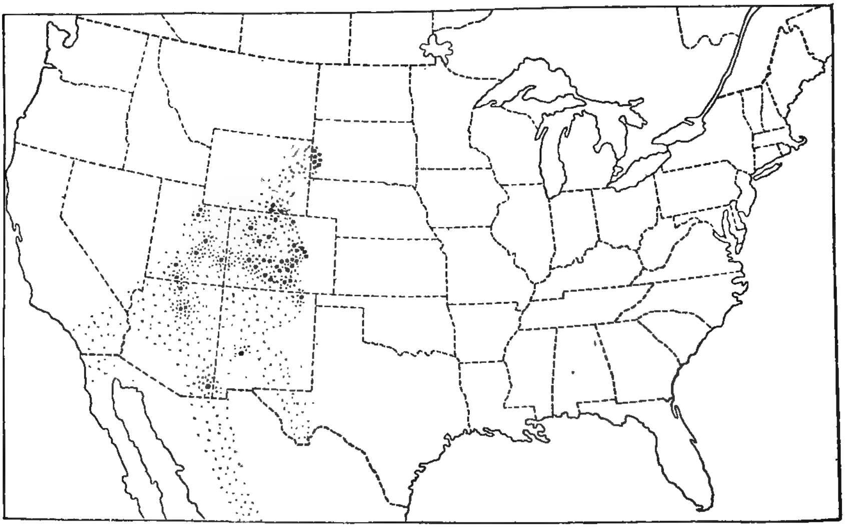


FIG. 59.—The Black Hills beetle: Distribution map. (Author's illustration.)

Forest, Colorado; Fredonia, Ariz.; Kanab, Escalante, Provo, Aquarius National Forest, Utah, and at Keystone, Wyo. It is represented in the forest-insect collection of the Bureau of Entomology by more than 10,000 specimens.

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Hopkins, 1902*b*, p. 10; Hopkins, 1902*c*, p. 21; Hopkins, 1903*a*, p. 59; Hopkins, 1903*b*, pp. 275–282; Hopkins, 1904, pp. 41, 43, 44; Hopkins, 1905, pp. 1–24; Hopkins, 1906, p. 4; Hopkins, 1907, p. 162; Hopkins, 1909, pp. 109–114.

No. 11. THE JEFFREY PINE BEETLE.

(*Dendroctonus jeffreyi* Hopk. Figs. 60, 61.)

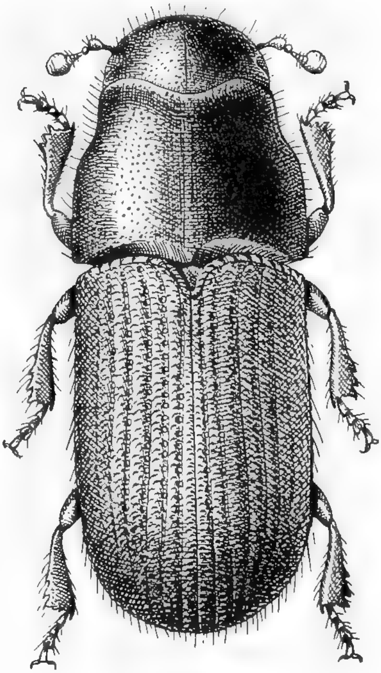

FIG. 60.—The Jeffrey pine beetle (*Dendroctonus jeffreyi*): Adult. Greatly enlarged. (Author's illustration.)

The Jeffrey pine beetle is a stout, black, cylindrical barkbeetle 6 to 8 mm. in length; the head broad, convex, with faint grooves behind and usually in front of the middle; the prothorax stout, broad, shining, the sides suddenly narrowed toward the head and the punctures fine; the elytra with moderately coarse rugosities between the rows of punctures, which are distinct on sides, the declivity with a few long hairs, the striæ on grooves narrow, and the intervening spaces broad and roughened with coarse granules. (See fig. 60.) It attacks living and dying Jeffrey pine and yellow pine, in the Yosemite National Park and San Bernardino County, California. It excavates long, nearly straight, egg galleries through the inner bark, and grooves the surface of the wood; the larval mines extend from the sides, exposed in the inner bark. The stout, whitish, grublike larvæ transform to pupæ and adults in cells at the end of the burrows, and the broods occupy the bark on the main trunk. The infested trees are indicated by pitch tubes on the trunks in the summer and fall, and during the following May to August by the fading and yellowish foliage.

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed in the bark on trees attacked the previous summer, as parent adults, larvæ, and developed broods of young adults.

ACTIVITY OF OVERWINTERED BROODS.

The spring activity of the overwintered broods appears to be similar to that of species 9 and 10. It appears that the overwintered broods begin to emerge from the dying trees toward the last of July, and to enter the bark of other trees to excavate their galleries and deposit eggs, but many, and perhaps the majority, of the overwintered broods do not emerge until after the middle of August. Some of the broods of the first generation probably develop before cold weather, but it is not likely that any of them emerge before the following July.

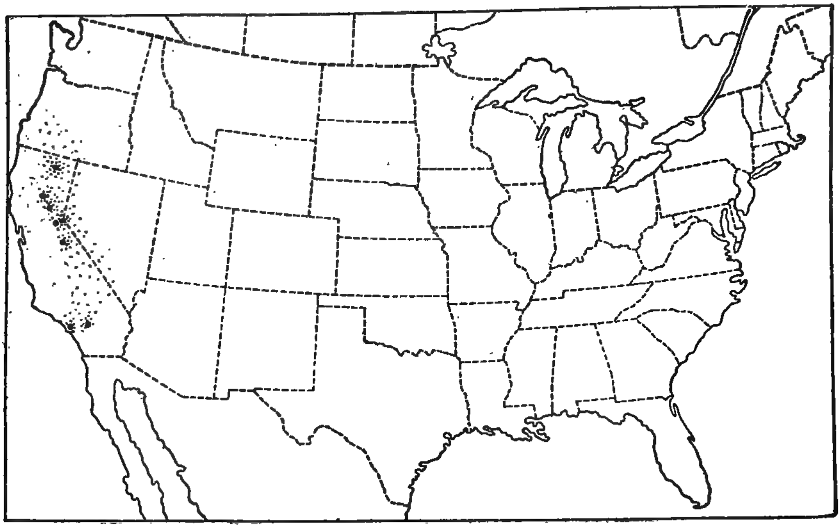

Fig. 61.—The Jeffrey pine beetle: Distribution map. (Author's illustration.)

HABITS.

The habits of this beetle appear to be quite similar to those of the mountain pine and Black Hills beetles. Therefore, while the details of its seasonal history and habits remain to be worked out, enough is known to show that it is a dangerous enemy of the Jeffrey and yellow pine, and that it will in all probability attack other pines within its range. Since the above was written the insect has been found to be quite destructive to the Jeffrey and western yellow pine in northern California.

METHODS OF CONTROL.

From what is known of the life history and habits it is evident that practically the same methods recommended for species 9 and 10 may be adopted for the successful control of this species.

BASIS OF INFORMATION.

Information on this species is based on investigations by Mr. H. E. Burke in July and August, 1906, along the rims of Little Yosemite and Yosemite, California, and by Mr. V. S. Barber, at Sterling and Chester, Cal., in 1907. Additional localities through correspondence are Nevada City, Tallac, Pinogrande, and San Bernardino, Cal.

This species is closely related to the mountain pine and Black Hills beetles, but is quite easily distinguished from them by the slightly more elongate, shining, and finely punctured prothorax.

BIBLIOGRAPHY.

Hopkins, 1909, pp. 114–116.

No. 12. THE EASTERN LARCH BEETLE.

(*Dendroctonus simplex* Lec. Figs. 62–64.)

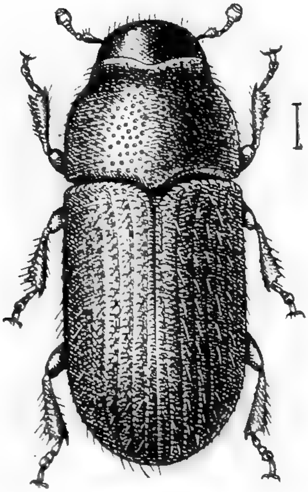

FIG. 62.—The eastern larch beetle (*Dendroctonus simplex*): Adult. Greatly enlarged. (Author's illustration.)

The eastern larch beetle is a stout, reddish to reddish-brown, cylindrical barkbeetle, 3.5 to 5 mm. in length, with broad, convex head, the prothorax short and strongly narrowed and constricted toward the head, the elytra with coarse rugosities between rows of indistinct punctures, the declivity convex and rather deeply grooved, the spaces between rather convex, and the body sparsely clothed with rather long hairs. (See fig. 62.) It attacks injured, dying, felled, and living eastern larch, from New Brunswick, Canada, westward to northern Michigan, and probably to the western and northern limit of this tree, and south in the higher Alleghenies to northeastern West Virginia and western Maryland. It excavates long, slightly winding egg galleries in the inner bark (fig. 63) and grooves the surface of the wood. The eggs are placed in alternate groups of three to six, or more, along the sides of the galleries. The short and broad, or sometimes long larval mines extend at right or oblique angles, and are exposed in the inner bark. The stout, whitish, grub-like larvæ transform in separate cells at the ends of the burrows in the inner bark. The broods occupy the bark of stumps and logs and the trunks of standing trees from the ground to the branches, or on into the tops. Fresh attacks on living trees cause a flow of resin or red boring dust in the loose bark and around the base of the trees. This species is capable of extensive depredations on the largest and best larch, but apparently prefers to infest injured, dying, and felled trees.

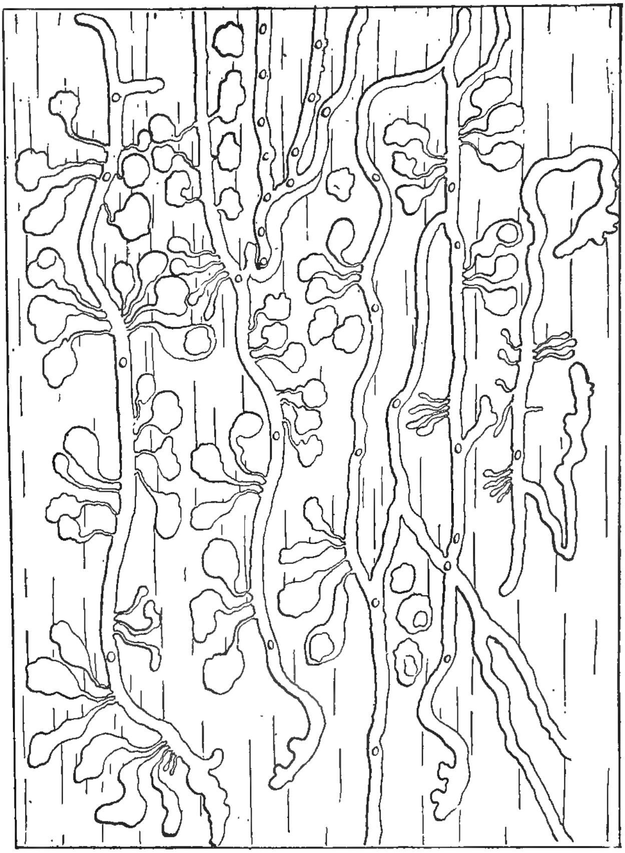

FIG. 63.—The eastern larch beetle: Egg galleries and larval mines. (Author's illustration.)

SEASONAL HISTORY.

While comparatively few details on the seasonal history of this species have been determined, it is evident that it passes the winter, principally in the adult stage, beneath the bark of trees, stumps, etc., attacked during the preceding summer, and activity begins with the first warm weather in April, May, or June. It also appears that there is but one generation annually, and, owing to the almost complete development of the broods in the fall, there is probably not much overlapping of the overwintered and new broods during the summer. The broods of the first generation begin to transform to adults toward the last of July, at which time all stages from parent adults to freshly transformed ones have been found.

ECONOMIC FEATURES.

Sufficient observations have been made to indicate that under favorable conditions this may be a very destructive species. Like most of its relatives, it attacks the largest and best trees, and when aided by defoliating insects, like the larch worm, or by other bark-beetles and bark-borers, it could easily devastate large forests. It is evident, however, that its preference for the bark on the stumps and logs of felled trees and those injured and dying from other causes renders it much less dangerous than most of the other species, and also much easier of control when it does attack the living timber.

Favorable conditions for its destructive work will be found in large forests of old matured larch undisturbed by the lumberman, where many trees have been defoliated by the larch worm or injured by fire, storms, etc., while unfavorable conditions for its work on the living timber will be found in sections where continued timber-cutting operations are carried on under a system of management requiring the utilization of the older living larch timber, as well as any that is dying or found to be infested with the beetle, as also when proper care is taken of the young timber to facilitate a vigorous healthy growth.

METHODS OF CONTROL.

Whenever it is positively determined that the larch is seriously injured or dying from the ravages of this species, the infested trees should either be barked, burned, or placed in water, and the stumps barked, during the period between September and the following May. Trap trees felled during May and June should serve to attract the beetles away from living trees and thus facilitate their destruction by removing the bark during the following fall and winter.

BASIS OF INFORMATION.

Information regarding this barkbeetle is based on investigations by the writer in northeastern West Virginia and northwestern Maryland, near Cranesville, W. Va., May, 1897, in northeastern Maine, June, 1900, and in northwestern Michigan, July and August, 1907, and by Mr. W. F. Fiske in northwestern Michigan, October, 1906. It is represented by more than 150 specimens in the West Virginia Agricultural Experiment Station collection and by 180 specimens in the forest-insect collection of the Bureau of Entomology.

This species is easily separated from its nearest relative, the Douglas fir beetle, by its smaller size and eastern distribution, and from eastern forms by its medium size, convex and deeply grooved declivity, the character of its gallery, and its occurrence in larch.

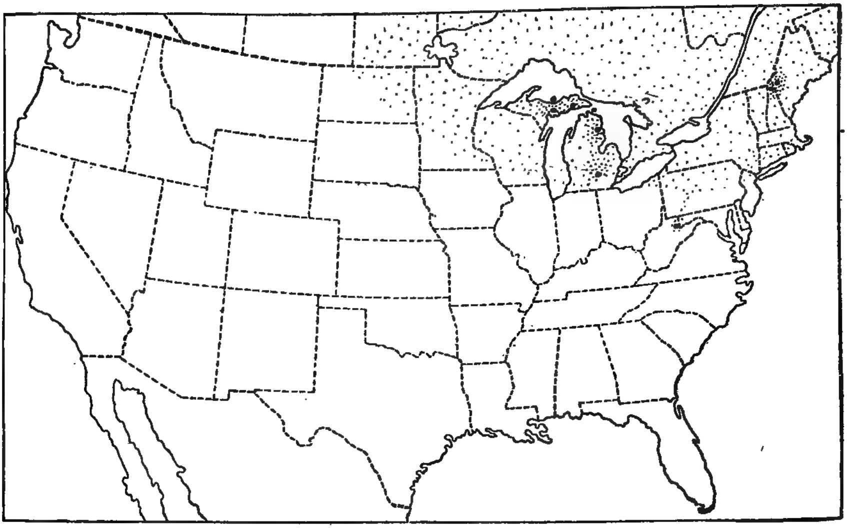

FIG. 64.—The eastern larch beetle: Distribution map. (Author's illustration.)

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Schwarz, 1888, p. 175; Packard, 1890 (under *Dendroctonus* sp.?), p. 903; Harrington, 1891, p. 27; Hopkins, 1898*b*, pp. 104–105; Hopkins, 1899*a*, pp. 394, 447; Hopkins, 1909, pp. 117–121.

No. 13. THE DOUGLAS FIR BEETLE.

(*Dendroctonus pseudotsugæ* Hopk. Figs. 65–69.)

The Douglas fir beetle is a stout, reddish to blackish-brown, cylindrical barkbeetle, 4 to 7 mm. in length, its head broad, convex, with shallow longitudinal groove behind the middle; the prothorax short, broad, punctured, with sides somewhat rounded and strongly narrowed and constricted toward the head; the elytra with rather coarse rugosities between the rows of punctures; the declivity convex, with striæ deeply grooved and intervening spaces convex and nearly smooth or roughened, and the body with numerous long hairs. (See fig. 65.) It attacks injured, dying, felled, and living Douglas fir, bigcone spruce, and western larch, wherever these trees grow from British Columbia southward into New Mexico, Arizona, and California. It excavates long, straight, or slightly winding egg galleries through the inner bark, and grooves the surface of the wood, the eggs being placed in alternate groups along the sides; the long larval mines extend at right angles from the main galleries and are exposed in the inner bark, often marking the surface of the wood (figs. 66, 67, 68). The stout, whitish, grublike larvæ transform to pupæ and adults in cells, either exposed or not, in the inner bark. The broods usually work independently of the other species, and often occupy and separate the bark on the lower to middle trunks of standing and felled trees. The fresh attack on living or freshly felled trees is indicated by red borings at the entrance to the galleries and lodged in the loose bark on the trunk or around the base; the leaves of the dying trees fade, turn pinkish yellow, or remain green in the fall succeeding spring and summer attack, but turn brown during the winter and spring.

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed in the inner bark of trees, logs, etc., attacked the preceding spring and summer, principally as developed broods of adults, but also as young to matured larvæ and probably parent adults.

ACTIVITY OF OVERWINTERED BROODS.

Activity begins during the first warm weather in April, when the parent adults extend their galleries and deposit eggs. The young adults of the developed broods begin to emerge by the middle of April, and continue to come out during June or July or later. The overwintered, large larvæ evidently complete their development and emerge by the first of August, while the broods of young larvæ of the possible second generation from eggs deposited in the fall evidently complete their development and begin to emerge in August, and continue to do so until cold weather, when some will begin their second hibernation as fully developed broods of adults.

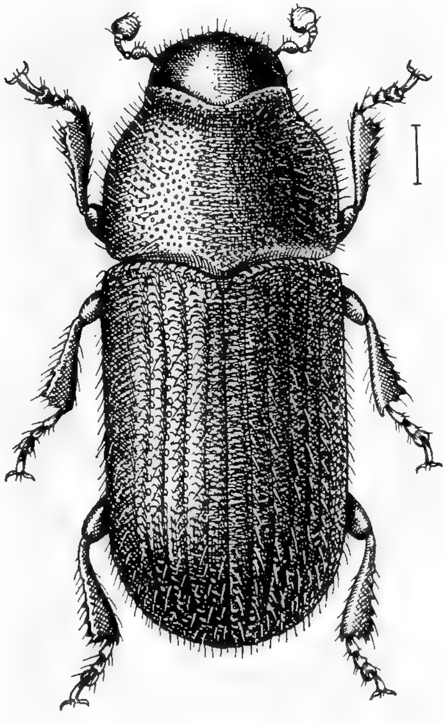

FIG. 65.—The Douglas fir beetle (*Dendroctonus pseudotsugæ*): Adult. Greatly enlarged. (Author's illustration.)

GENERATION.

The overwintered broods of adults begin to attack the trees, excavate new galleries, and deposit eggs about the middle of April. The principal attack is during April, May, and June, but may continue into July or later. The eggs begin to hatch soon after they are deposited, and the larvæ begin to feed and continue to develop during May, June, and July, into August or later, some retarded individuals continuing to feed until cold weather. They begin to transform to pupæ and adults during the latter part of July and continue their transformations during August until hibernation begins. There is some evidence that a few of the more advanced broods may emerge during September and October and deposit eggs for the second generation during September and October, but it is probable that these late-emerging broods are in the majority of cases those developed from overwintered broods of young larvæ or from eggs deposited in the spring by overwintered parent adults. It is very evident, however, that there is quite a complete development of the first generation before the first of October, which accounts for the passing of the winter principally as fully developed adults.

HABITS.

This species prefers to infest the stumps and logs of felled trees, and injured and dying standing ones, in which it breeds in great numbers, but in some localities and under favorable conditions it will attack healthy living trees and cause their death. So far as known, it breeds exclusively in the Douglas fir, bigcone spruce, and western larch. The trunks of standing trees from a foot in diameter to the large older ones are attacked from the ground to the middle portion of the trunk, and sometimes to the lower branches. The stumps, logs, tops, and larger branches of felled trees are favorite breeding places and are usually thickly infested.

The parent adults enter from the crevices and depressions in the bark, excavate entrance burrows through the outer and inner bark, and then extend their long, longitudinal egg galleries through the inner living or dying bark. As the gallery is extended, the female places her eggs in alternate groups along the sides, and when one gallery is completed she either remains in the gallery until she dies or leaves it to excavate a new one. The larvæ, upon hatching, begin to feed on the inner bark and to extend their food burrows at right or oblique angles to the mother gallery. Instead of the burrows being short and broad like those made by many other species, they are often extended to a length equaling or exceeding that of the mother gallery, and cross each other in such a manner as to completely girdle the tree and separate the bark so that it is easily removed from the wood. The larvæ transform to pupæ and adults in individual cells at the ends of their burrows, and when the adults are fully matured they bore through the intervening bark and congregate in broad cavities beneath the bark, remaining thus over winter, and until they begin to emerge in the spring. Their habit of flight is not well known, but they evidently fly or swarm in the evening or early part of the night.

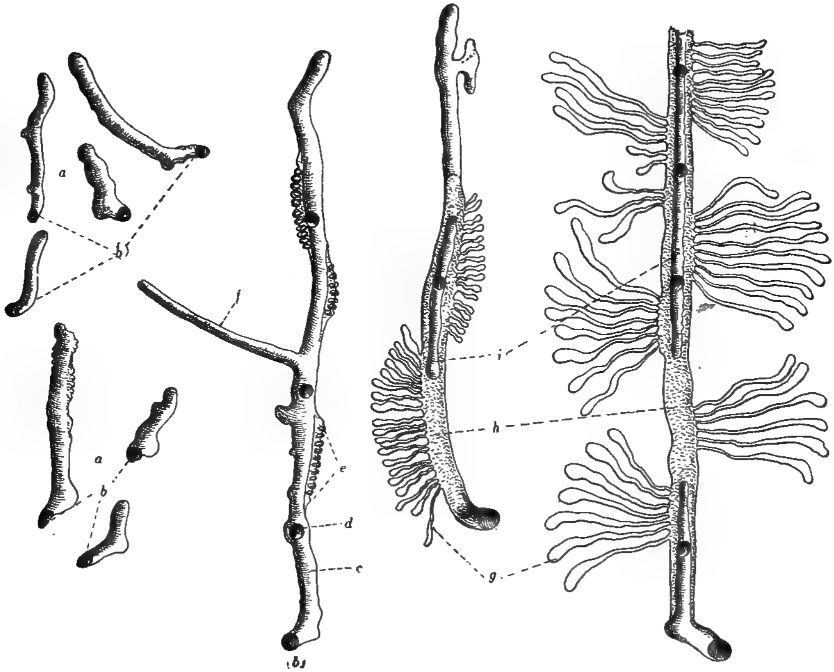

FIG. 66.—The Douglas fir beetle. Egg galleries and larval mines: *a*, Beginning or basal sections of egg galleries in bark; *b*, entrance; *c*, egg gallery; *d*, ventilating hole; *e*, egg nest; *f*, abnormal branch; *g*, larval mines; *h*, egg gallery packed with borings; *i*, subsequent passage or inner gallery through borings. (Author's illustration.)

ECONOMIC FEATURES.

The preference shown by this species for the bark of logs and stumps of felled and injured trees makes it of less economic importance than the Black Hills beetle and some of the other species, but in some of the localities, especially in Idaho and southward to southern Colorado and northern New Mexico, it attacks the living timber and causes extensive losses of the best as well as of the inferior Douglas fir.

EVIDENCES OF ATTACK.

The first evidence of attack on living trees is the appearance of reddish boring dust in the crevices of the bark, lodged in the loose bark on the trunk and around the base, and on the ground around its base, which is the only external evidence of attack or infestation until in the fall and winter, when the leaves on some of the trees will begin to fade and turn pinkish or yellowish, while on other trees they will not begin to change color until next spring, and on still others only the leaves of the top or lower branches on one side of the crown will die, while the remainder will continue green, thus indicating that only a portion of the bark is killed and infested. While the fading and dying of the leaves result from infestation by this beetle, this may, and does, sometimes result from other causes, so that the only positive evidence of injury or destruction of Douglas fir or western larch in any locality by this species can be determined only by cutting into the bark of the freshly attacked or dying trees and finding the characteristic galleries and larval mines occupied by authentically identified parent beetles or their broods.

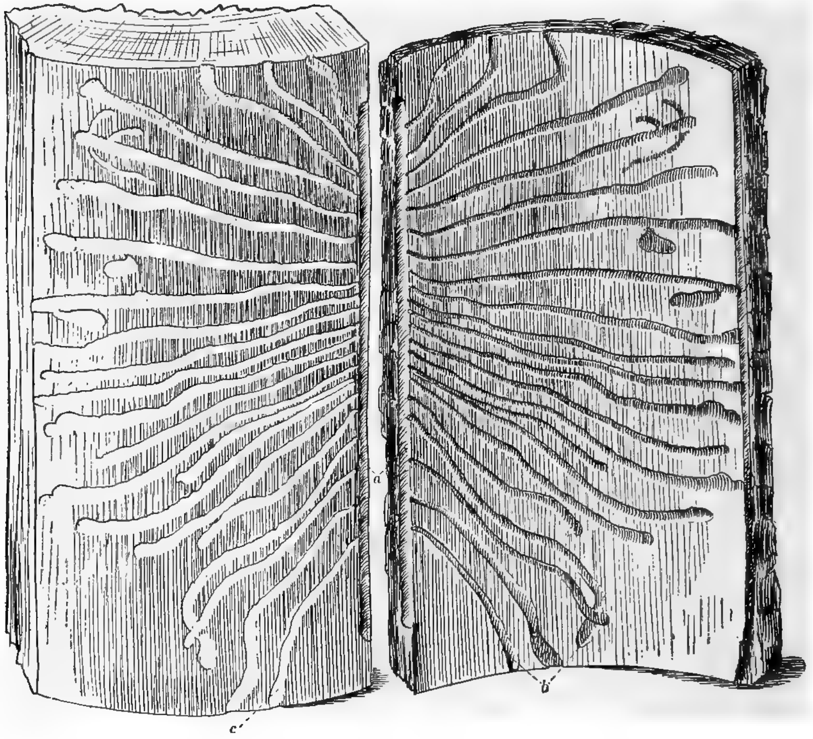

FIG. 67.—The Douglas fir beetle. Egg gallery and larval mines: *a*, Egg gallery in bark and grooved in surface of wood; *b*, larval mines in bark; *c*, larval mines marked and slightly grooved on surface of wood. (Author's illustration.)

As a rule, the broods leave the trees before the leaves have turned reddish brown or fallen, and they never return to the trees to excavate galleries and deposit eggs for new broods after all of the bark is dead, since they must have either living or partially living bark for their eggs and young larvæ.

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

The commercial value of the Douglas fir trees killed by the beetle is not seriously impaired for several years after they die, except that the sapwood discolors and otherwise deteriorates, but the heartwood of large trees may remain sound for twenty years or more. On the other hand, if they are seriously attacked by wood-boring insects the wood may deteriorate rapidly.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication and destructive work of this bark-beetle are found in the drier regions, where the growth of the trees is slow and where the older trees are frequently injured by fire, storms, landslides, etc., as also in the more isolated sections of the forests in such a region where no continued timber-cutting operations are carried on. Unfavorable conditions for attack on living timber are found in moist regions, where the growth of the trees is vigorous, as in the coast, Cascade, and Sierra sections of Washington, Oregon, and California, and especially in those sections in which continued timber-cutting operations are carried on under a system of lumbering or forest management which requires that the matured or older timber, as well as that which is dying and "beetle infested," be taken out, and where the younger, vigorous timber is protected from injury by fire and other causes.

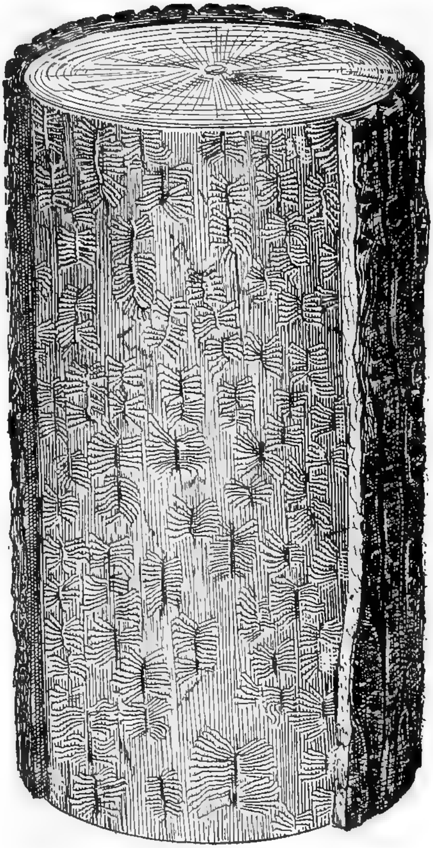

FIG. 68.—The Douglas fir beetle: Section of log with bark removed, showing brood galleries marked and grooved on surface of wood. (Author's illustration.)

METHODS OF CONTROL.

Whenever in a given locality it is positively determined that this species is attacking and killing the Douglas fir, bigcone spruce, or western larch, and that the bark of living and dying trees contains living parent adults or developing broods, efforts should be made toward its control. The individual trees and groups of trees attacked during the spring and summer should be located and marked during August and November. In order to effectively check its ravages, at least 75 per cent of the infested trees should have the infested bark removed from the main trunks or the logs converted into lumber and the slabs burned during the period beginning with the first of November and ending with the first of the following March.

The simple removal of the bark during this period, without burning it, will be sufficient to kill the broods. The bark may be removed from the trees as they stand or after they are felled, as may in each case be most convenient or desirable.

The operations should be confined first to the worst infested localities and to the larger clumps of infested trees. Therefore explorations should be made from time to time to determine the principal localities in which the ravages of the insect are sufficiently extensive to require special attention.

If it is more convenient or practicable to fell the trees and roll the infested trunks together and burn them, the work should be done during the winter months.

With this species the barking of newly infested trees during July and the first half of August is permissible and sometimes desirable, because this is the period in which the principal larval development takes place and before the broods of adults have sufficiently matured to fly when liberated from the bark. By the last of August some of the adults have developed sufficiently to fly; therefore the infested trees should not be barked during the latter part of August and through September and October.

The fact that this species is attracted to the living bark on the trunks and stumps of recently felled trees suggests the efficiency of the trap-tree method of control. Whenever it is found desirable to adopt this method living trees should be felled in August and April and have the bark removed or the logs utilized and the slabs burned to kill the broods, the former during the winter months and the latter during the following July and the first half of August. Experiments with girdled trap trees show that girdling is by no means as effective as felling.

Continued timber-cutting operations within a given locality, especially in the coast region, usually serve to protect the living timber from attack by this beetle, because the stumps, logs, tops, and broken or injured Douglas fir trees furnish all the requirements for its breeding, and the utilization of infested logs destroys large numbers of the beetles. If, however, the living timber in the vicinity of cuttings should at any time become threatened by an invasion from the cuttings, or if it be desirable to include in timber-cutting regulations certain provisions for the burning of the slash, this work should be done during the period beginning about the first of October and ending by the first of March.

BASIS OF INFORMATION.

The information relative to this beetle is based on investigations conducted by the writer at Guerneville and McCloud, Cal., Grants Pass, Corvallis, Newport, Detroit, and St. Helen, Oreg., Port Angeles and Port Williams, Wash., Sand Point, Kootenai, and Hailey, Idaho, April and June, 1900; at Kootenai, Idaho, and Junction, Wash., August, 1902; at Tercio, Colo., and Fieldbrook, Cal., May, 1903; at Colorado Springs, Colo., October, 1905, and at Fort Garland, Colo., in 1906; by Mr. H. E. Burke, at New London, Rock Creek, Kent, Satsop, Hoquiam, North Bend, Pialschie, Des Moines, Ashford, and Meredith, Wash., May to October, 1903, June to September, 1904, May to September, 1905, and April and May, 1906; at Smiths Ferry, Idaho, October, 1904; in San Mateo County, Cal., May, 1906; at Panguitch and Panguitch Lake, Utah, July to September, 1907; by Mr. J. L. Webb, in the San Francisco Mountains, Arizona, June, 1904; at Centerville, Stites, Kooskia, and Pioneerville, Idaho, from June to September, 1905; in the Chiricahua National Forest, and the Sacramento National Forest, Arizona, June to September, 1907; by Mr. W. F. Fiske, at Capitan and Cloudcroft, N. Mex., March to June, 1907. Additional localities through correspondence and from other collections are Belton, Ovondo, Bozeman, Kalispell, and Leavenworth Valley, Mont.; Orting and Dole, Wash.;

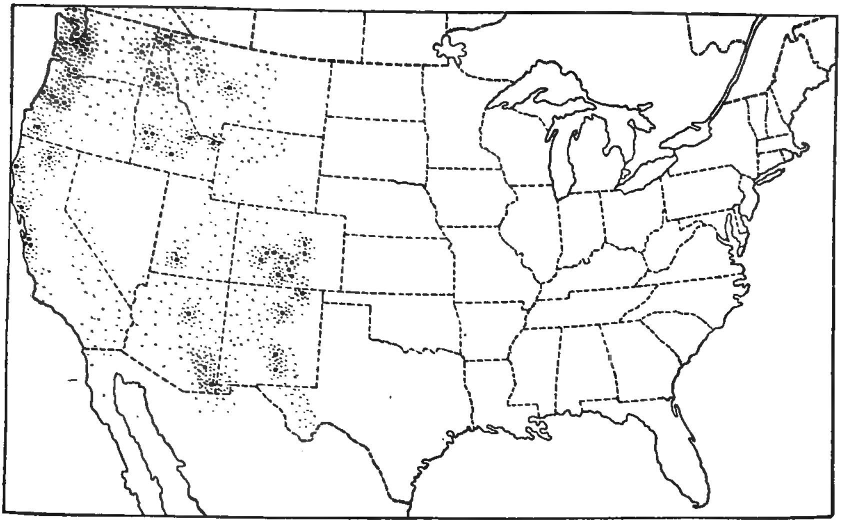

FIG. 69.—The Douglas fir beetle: Distribution map. (Author's illustration.)

Santa Fe, N. Mex.; Henrys Lake National Forest and Beaver Canyon, Idaho; Ventura County, Cal., and Vancouver, British Columbia. It is represented in the forest-insect collection of the Bureau of Entomology by more than 700 specimens, including all stages and work.

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No. 14. THE EASTERN SPRUCE BEETLE.

(*Dendroctonus piceaperda* Hopk. Figs. 70–77.)

The eastern spruce beetle is a reddish-brown to black barkbeetle, 5 to 6 mm. in length, the body sparsely clothed with long hairs, the head broad and convex, the pronotum often darker than the elytra, with the sides distinctly narrowed and constricted toward the head and the punctures of irregular sizes and moderately coarse, the elytra with coarse rugosities between rows of indistinct punctures, and the elytral declivity somewhat flattened, smooth, and shining in the male, more convex, roughened, and less shining in the female. (See fig. 70.) It attacks the red, black, and white spruce from New Brunswick, Canada, southward in the mountains of New York and Pennsylvania, and westward to Michigan. The adult bores through the outer bark to the inner living portion, extends its egg gallery (figs. 71, 73) longitudinally through the inner bark, and grooves the outer layers of wood (fig. 72). From ten to thirty or more eggs are deposited close together in elongate cavities in the sides of the egg gallery. The larvæ soon hatch and begin to feed on the bark. At first the larval mines are usually connected, forming a common cavity, but later each larva excavates an independent mine, which it extends in a generally transverse but irregular course from the egg gallery, with the transformation cell at the farther end in the inner bark or between the inner and outer bark; but, like their larval mine, this is usually exposed on the inner surface. The presence of this insect in standing living or dying trees is indicated by reddish boring-dust in the crevices of the bark, by pitch or gum tubes, and by the fading and falling of the leaves, or by the bare reddish appearance of the twigs. It is a very destructive enemy of mature red and white spruce.

SEASONAL HISTORY.

(See fig. 75.)

OVERWINTERING STAGES.

The winter is passed in the inner bark of trees in which the insect developed the previous summer, as adults and all stages of larvæ.

ACTIVITY OF OVERWINTERED BROODS.

There is some evidence that a few parent adults hibernate in galleries started the previous fall and that they may begin activity somewhat earlier than the overwintered broods. The overwintered, developed adults begin to emerge about the middle of June and continue emergence until August, or later, the principal emergence taking place during July. They begin to attack the trees and excavate galleries soon after they emerge, and by the 19th of June begin

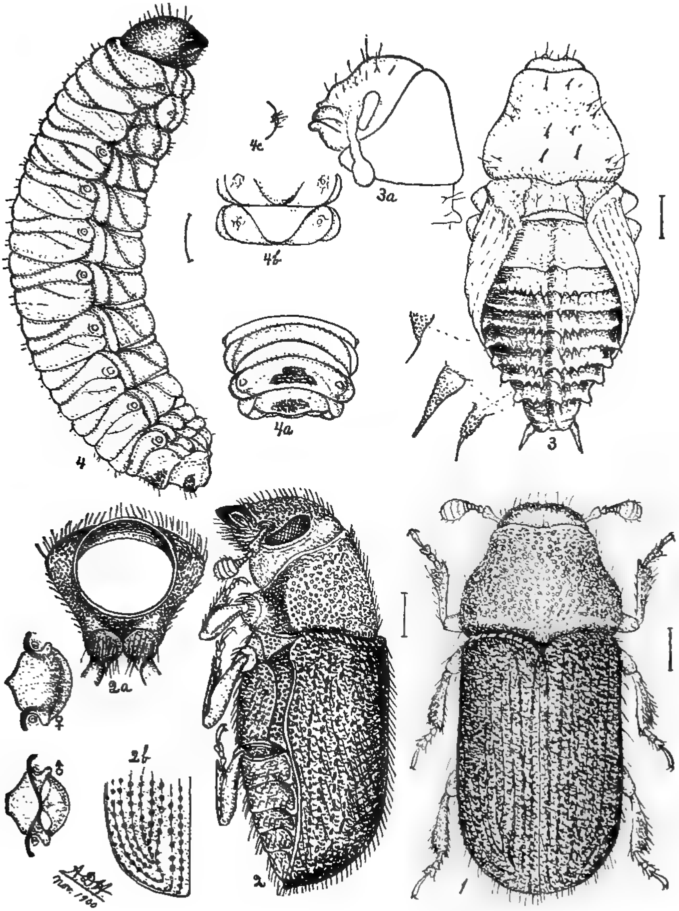

Fig. 70.—The eastern spruce beetle (*Dendroctonus piceaperda*): *1*, *2*, Adult, dorsal and lateral aspects; *2a*, *2b*, ♂, ♀, details of adult; *3*, pupa; *3a*, lateral aspect of head and prothorax of pupa; *4*, larva; *4a*, *4b*, *4c*, details of larva. All greatly enlarged. (Author's illustration.)

to deposit eggs. The work of excavating galleries and depositing eggs is principally during June and July, but may be continued until September, or later (as evidenced by the finding of young larvæ in October, and the same, after overwintering, the following May.)

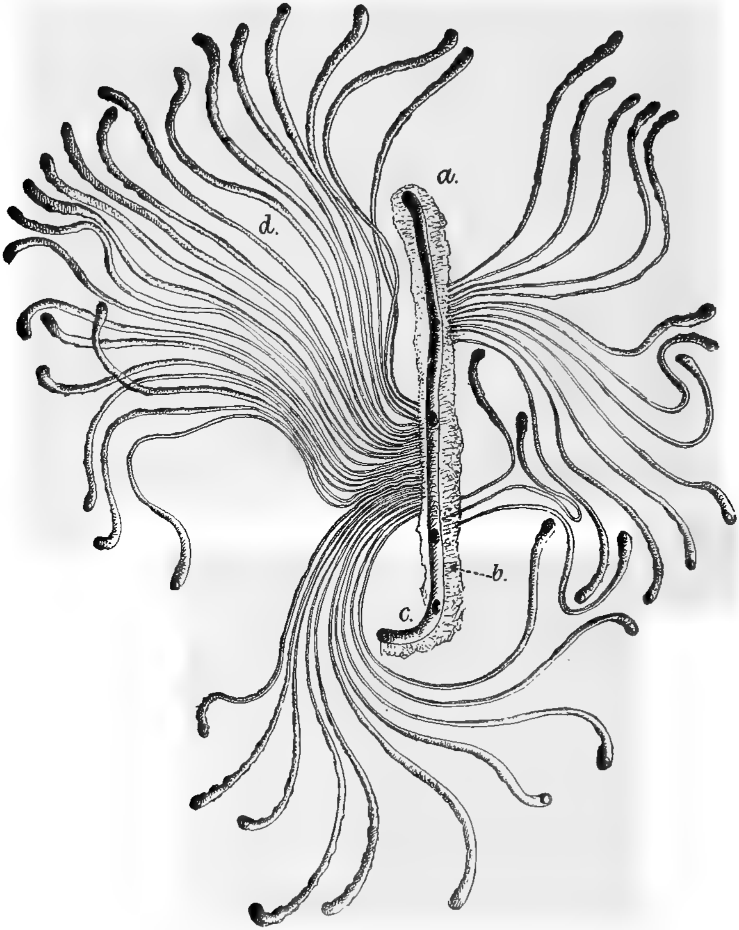

FIG. 71.—The eastern spruce beetle. Egg gallery and larval mines: *a*, Egg gallery; *b*, boring dust packed in gallery; *c*, entrance and subsequent or inner gallery; *d*, larval mines. (Author's illustration.)

The overwintered broods of larvæ begin activity during the last week in May and first week in June. The matured larvæ begin to transform to pupæ and adults during the first week in June, and continue to do so, while the younger larvæ are developing, until July or later. All have evidently transformed and emerged by the middle of August, or earlier.

GENERATION.

The eggs deposited by the overwintered broods of adults begin to hatch during the latter part of June (fig. 72) and the first part of July, and continue to hatch during July and August. The larval development is confined principally to July and August, but may continue to October. The more advanced larvæ begin to transform to pupæ and adults during the last week in August and first week in September, and continue to do so until hibernation begins in the fall. No evidence has been found that any of the broods emerge from the trees in the fall; therefore there is but one generation annually. By far the greater number of the broods pass the winter as young to matured adults, and the hibernation begins about the middle of October.

HABITS.

This species prefers to attack the older mature living timber. It also attacks standing timber weakened or injured from other causes, and trees felled by storm and otherwise, though usually not in such

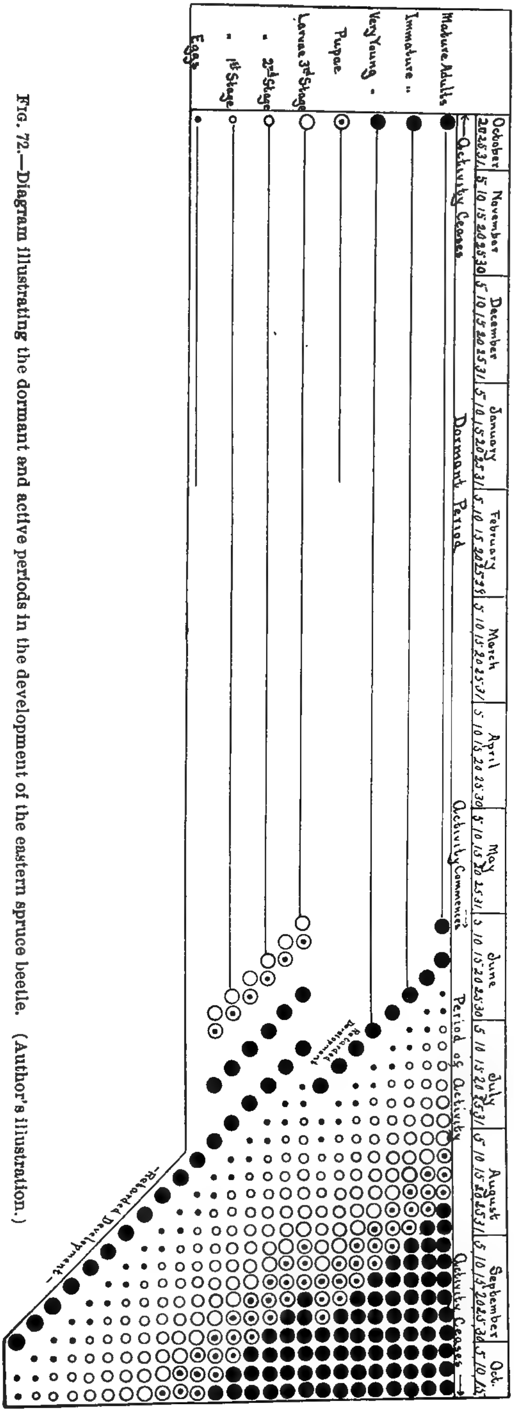

FIG. 72.—Diagram illustrating the dormant and active periods in the development of the eastern spruce beetle. (Author's illustration.)

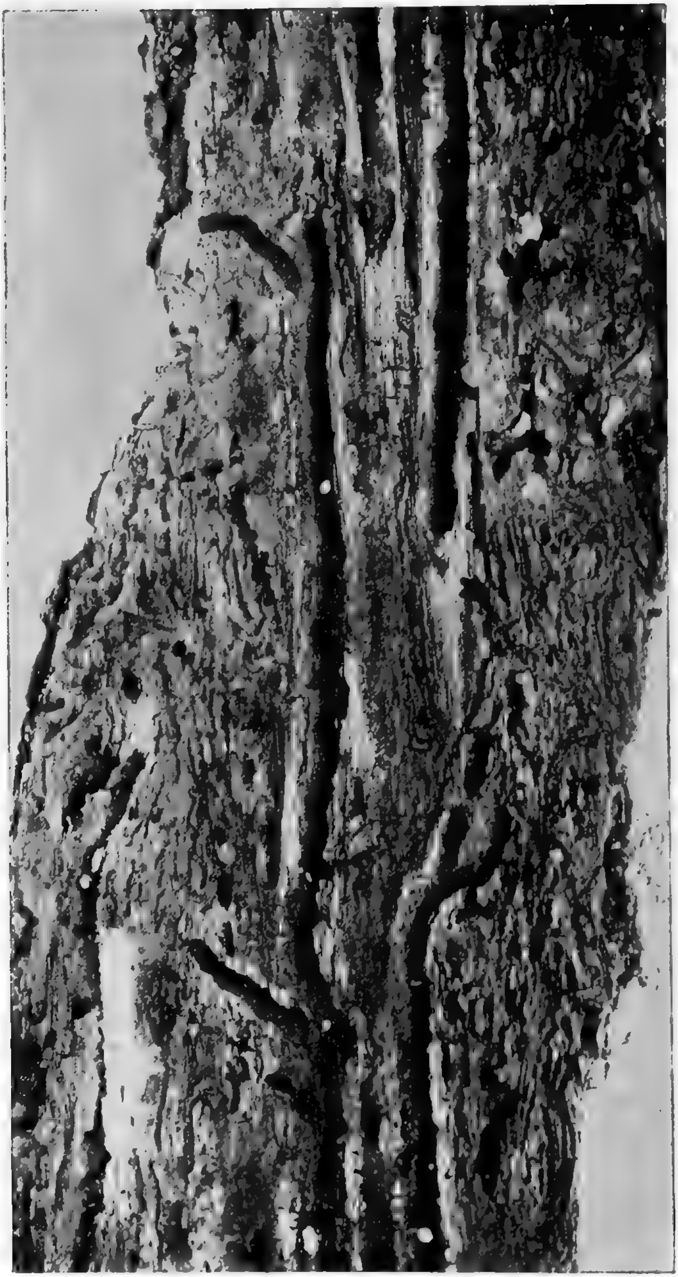

FIG. 73.—The eastern spruce beetle: Old egg galleries and larval mines in bark. (Author's illustration.)

numbers as it does the living, standing trees. It infests the red spruce, black spruce, and white spruce, but, so far as known, does not attack any of the pines or the larch.

The beetles enter the bark of healthy trees at a point from 6 to 10 feet from the base, and that of trees weakened by disease or other causes from near the base to the larger branches.

In the living trees the entrance burrow is gradually extended obliquely upward, or subtransversely, thence in a longitudinal direction upward through the inner bark and often grooving the surface of the wood. Along the sides of this gallery, which is usually about three times as broad as the beetle, the eggs are placed singly in small cavities or in groups in an elongated cavity. The eggs are then protected by a mass of borings, closely packed and cemented with gum, which, with the exception of a small inner burrow or subgallery, fill up the broad egg gallery. The original entrance is first packed; then an opening to the outside is made in the roof of the gallery a few inches from the entrance, another section is excavated and packed, another hole is made through the roof, and so on until the gallery is completed. After all is finished the adults make one or two short, irregular, lateral branches at the farther end, apparently for an abiding place until they die.

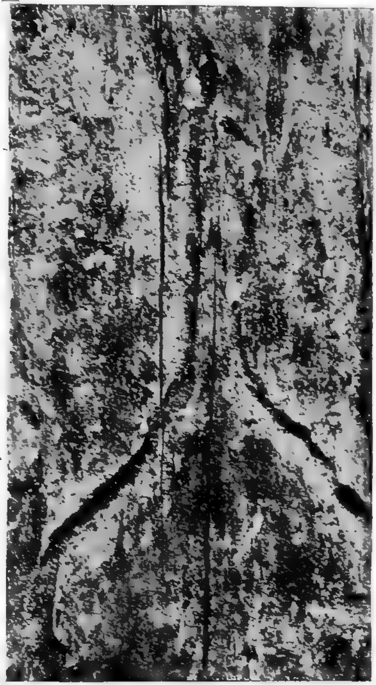

FIG. 74.—The eastern spruce beetle. Old galleries marked on surface of tree: Grooves on surface of wood of tree that has been dead about twelve years. (Author's illustration.)

The gum flowing into the wounds made by the beetles when they are excavating the entrance is pushed out and the holes kept open through it, thus forming the pitch tubes, which are so conspicuous on the bark of freshly attacked trees. After the vitality of a tree is weakened by numerous wounds and by an excessive flow of resin the subsequent entrances are not marked by pitch tubes. Or, if a tree is decidedly weakened from other causes before it is attacked, or when a large number of beetles is boring into the outer bark, and the boring-dust falls down and lodges in the flakes of bark and in the moss on the tree, pitch tubes are not formed.

When the eggs hatch, the minute white grubs or larvæ eat their way into the soft inner bark, which by this time has commenced to die and is in the best condition for their food supply. When the eggs are deposited in separate cavities, each larva makes a separate mine, but when they are massed along the sides, or placed close together, as they usually are, the larvæ work side by side and consume all of the inner layer of bark until they have progressed some distance, when they begin to separate and each larva makes an independent mine. While the individual burrow may cross and recross its neighbor, it preserves a course of its own and increases in width as its occupant increases in size, until the larva ceases to feed. The latter then excavates a cavity, either in the bark next to the wood or next to the outer dry bark, where in due time it changes to the pupa. Here it remains in a semidormant condition until the legs, wing covers, and other parts develop. It then sheds its outer skin and becomes an adult winged beetle, soft and yellow at first, but gradually hardening and becoming darker.

When the individuals of a brood are fully matured in the spring, they bore through the inner bark between the transformation cells and congregate in the larger common chamber thus formed until it is time for them to emerge. They then bore their way out to the surface and emerge to fly in search of suitable trees in which to excavate galleries and deposit eggs. Scarcely anything is known of the flight habits, but the beetles probably fly during the evening or at night.

ECONOMIC FEATURES.

CHARACTER OF ATTACK AND INJURY.

So far as known, this beetle confines its attack to the spruce in the region north of latitude 43°. Toward its southern limit it evidently does not occur at altitudes below 2,000 or 2,500 feet, while at latitude 47° in Maine and in extreme northern Michigan it would be found below an altitude of 600 feet. It is rarely found in trees under 10 inches in diameter breast high, but prefers those 18 inches or more in diameter. Whenever it occurs in sufficient numbers to attack and kill large numbers of trees the flying beetles within a given locality usually concentrate on groups or patches of timber of greater or less extent. The trees die from the attack, and when the new broods develop they emerge from the dying trees and settle on the living timber in another locality, and so on, until all of the matured timber is killed. They usually settle on a tree and enter the bark in such numbers that there is little chance for its recovery. Their numerous egg galleries are extended through the most vital part of the tree (the cambium), where the new growth of wood and bark takes place. Thus the injury produces a weakened condition of the tree. This is

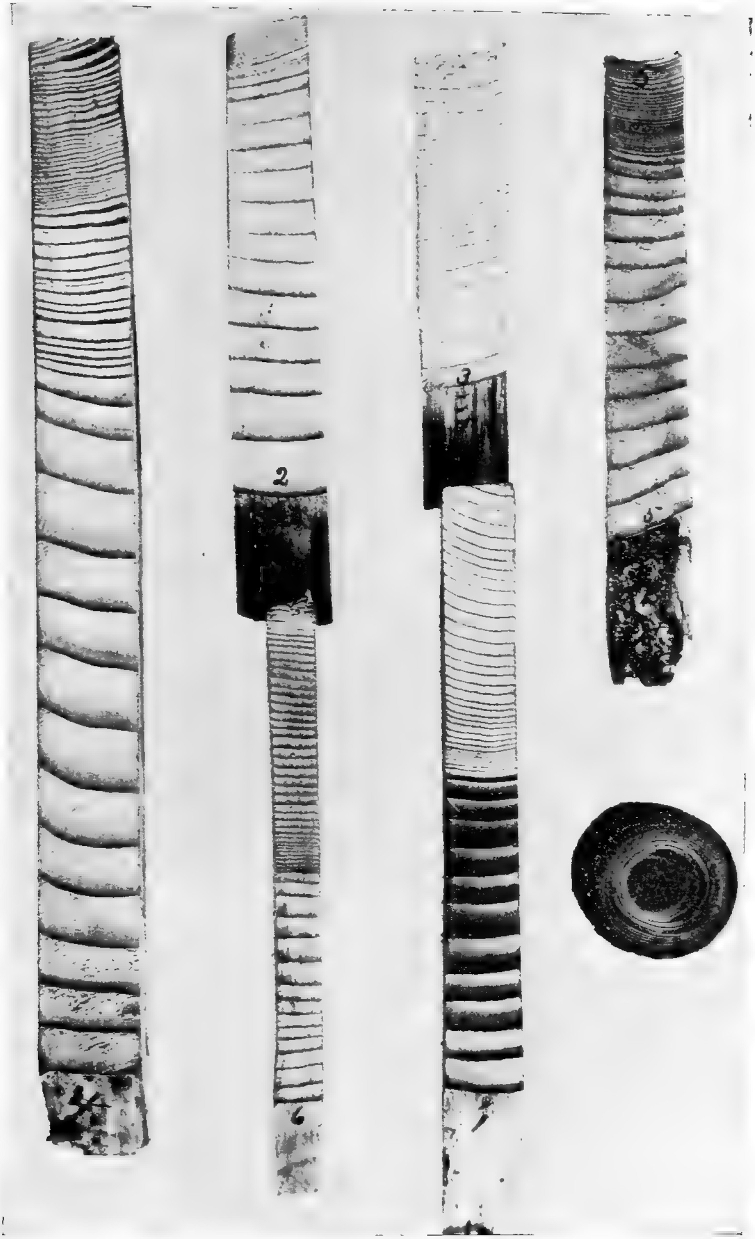

FIG. 75.—Balsam fir chips showing annual growth, indicating dates of death of spruce trees. *1*, From tree by dead spruce in cutting of about 1888; *2*, from tree standing by dead spruce in old cutting of about 1886; *3*, from tree standing by dead spruce which showed the work of the eastern spruce beetle (tree evidently died about 1888); *4*, from fir in blow-down of about 1871, which was followed by another in about 1885–6; *5*, from tree in blow-down of about 1886; *6*, from spruce standing by large spruce tree which was broken by a storm of about 1886 (evidence was found in this tree that it was living when felled and that it had been attacked, after falling, by the eastern spruce beetle; both galleries and remains of beetles were found in the bark); 7, section of small suppressed spruce about forty-five or fifty years old. All natural size. (Author's illustration.)

followed by the lateral extension of the larval mines of the young broods, which serves to completely girdle the tree and kill the inner bark, and this in turn is followed some months later by the gradual or sudden dying of the leaves and the complete death of the tree.

The trees on which a successful attack is made in June or July will have the leaves faded and fallen by October, but the leaves on those attacked in August or later may remain normal until the following May or June before they fall.

EXTENT OF DEPREDATIONS.

The evidence we have been able to collect shows that at various times during the past century this beetle has been the cause of the death of an enormous amount of the best matured spruce timber in the forests from New Brunswick to northern New York and in places in Canada. It is also evident that it will continue to be a menace to standing matured timber, probably throughout the region in which the red and white spruce prevail in forest growth.

In a report by C. W. Johnson (1898, pp. 73–74), reference is made to extensive destruction of red spruce in the mountains north of Stull, Wyoming County, Pa., supposed to have been caused by a Dendroctonus identified as *D. rufipennis*. Specimens collected by Mr. Johnson have been examined by the writer and found to be *D. piceaperda*. Mr. Johnson stated that some 5,000,000 feet of spruce had been killed on the lands of one company, apparently during 1896 and 1897.

EVIDENCES OF ATTACK.

The first evidence of attack on living trees is reddish boring dust lodged in the loose bark and moss on the trunk and around the base of the tree, or numerous fresh gum spots or pitch tubes mixed with whitish or reddish borings on the bark of the middle or lower portion of the trunk. When this is found it will indicate that the beetles are actively at work excavating the galleries in the bark. After this work is completed and the broods of larvæ have killed the inner bark the pitch tubes have an old or dried appearance and the boring dust is less evident. By the time the larvæ have developed and transformed into pupæ and adults during September and October the infested trees are indicated by the faded pale-green appearance of the needles on the trees or on the ground, and by the reddish appearance of the tops from which the needles have recently fallen. During the winter and following spring the trees that were attacked later in the preceding summer will present the same evidence of infestation, and in addition a large percentage of the infested trees are usually marked by woodpecker work. The birds discover the broods of beetles and larvæ, and in their efforts to get the insects they remove a sufficient amount of the outer loose bark to give the trunks a conspicuously reddish appearance, so that even when the leaves on an infested tree are perfectly normal and there are no pitch tubes the trees thus marked by the birds can be readily located as infested trees.

As a rule, after the middle of June all of the broods of this insect have left the trees from which the leaves have fallen, and certainly those in which the twigs have changed from a reddish to a grayish appearance. With few exceptions this may be depended upon, because the parent beetles must have living bark in which to deposit their eggs, so that the freshly hatched larvæ will have the proper conditions for their future development. Therefore it is seldom that more than one set of broods develops in the same tree. This can happen only when but one side of the trunk or the upper or lower portion is infested and the remainder is not dead when the broods emerge. In this case the remaining living bark will be attacked and yield another set of broods.

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

The wood of the trees killed by this beetle is not materially reduced in value for several years afterwards, except in so far as the sapwood and heartwood is stained and injured by wood-boring insects, decay, fire, etc.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication of this insect are found in large areas of virgin forest, where there is a thick stand of old matured timber and where some of the trees have suffered from injury by storms, landslides, lightning, or other causes. If, under such conditions, the beetle be present in considerable numbers, it may multiply so rapidly that the best timber in the forests over hundreds of square miles may be killed within two or three years, as has been demonstrated by a number of notable outbreaks in Maine. Unfavorable conditions are found in young, vigorous forests from which the old timber has been removed and utilized, and especially in forests which are under a modern system of forest management, with regulations either requiring that the matured timber be utilized or that all injured or dying trees found to be infested with the beetle be felled and barked or floated at the proper time to kill the broods.

METHODS OF CONTROL.

Whenever it is positively determined that this species is attacking the living spruce in a given locality, or that the bark of living and dying trees contains living parent adults or developed broods, some measures should be adopted without delay for its control.

The removal of the infested bark from the trunks of the trees without burning is all that is necessary to kill the immature stages of the insect at any time. If the work be done during the period beginning with the middle of October and ending with the middle of May, say at or below an elevation of about 1,800 feet at latitude 45°, the parent adults and developed broods of adults, together with the immature broods, will be killed. The infested parts of the trunks may be barked without felling the trees, or the trees may be felled for this purpose and barked or utilized and the slabs burned, as in each case may be more practicable or desirable. If the timber can not be utilized for several years it will remain sound much longer if barked and left standing than if felled.

If, in the case of a moderate attack, the larger clumps or patches of infested trees and the more accessible scattering ones in the worst affected sections of a forest are barked, it should serve to bring the insect under control the first year, but in the case of a very extensive attack this may require several years.

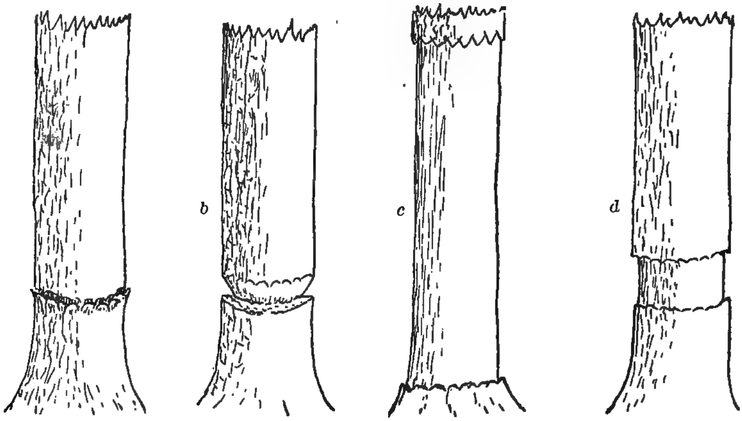

FIG. 76.—Trees girdled by different methods: *a*, Hack-girdled; *b*, girdled to heartwood; *c*, hack-girdled and peeled; *d*, hack and belt girdled. (Author's illustration.)

It is not necessary that every infested tree should be barked or utilized, but it is important that at least 75 per cent of such trees be either barked or removed in regular logging operations, before the broods have time to emerge.

Whenever a large amount of timber is being killed, as in northwestern Maine in 1900, the regular logging operations should be conducted in the principal infested areas, in order that the infested trees may be cut and floated out of the forest before the broods have time to emerge. The adoption of this method by the Berlin Mills Company in 1901 was evidently very successful in controlling the insect in the region referred to in Bulletin 28 of this office.

It may be practicable to bark newly infested trees in August and September, but the principal work of barking, or removal, or utilization in the regular logging operations, should be done between the middle of October and the middle of May.

With this insect it may be practicable to utilize trap trees to attract the insects away from the healthy timber. For this purpose living trees, the necessary number depending on the extent of infestation, should be girdled to the heartwood during June. (See fig. 76.) If they become infested during the summer they must be barked or removed by the middle of the following May, in order to destroy the broods.

BASIS OF INFORMATION.

The preceding information on the eastern spruce beetle is based on investigations by the writer in northwestern Maine in May and June, 1900, and at Waterville, N. H., in May, 1903; on experiments with girdled trees by Mr. Austin Cary during the summer of 1900, and instructions to the Berlin Mills Company, in cutting infested timber, in 1901, and on investigations by Mr. W. F. Fiske on Grand Island, Michigan, in October, 1906. Additional localities from correspondence and other collections are West Stewartstown, N. H., Anticosti, Canada, and Pennsylvania.

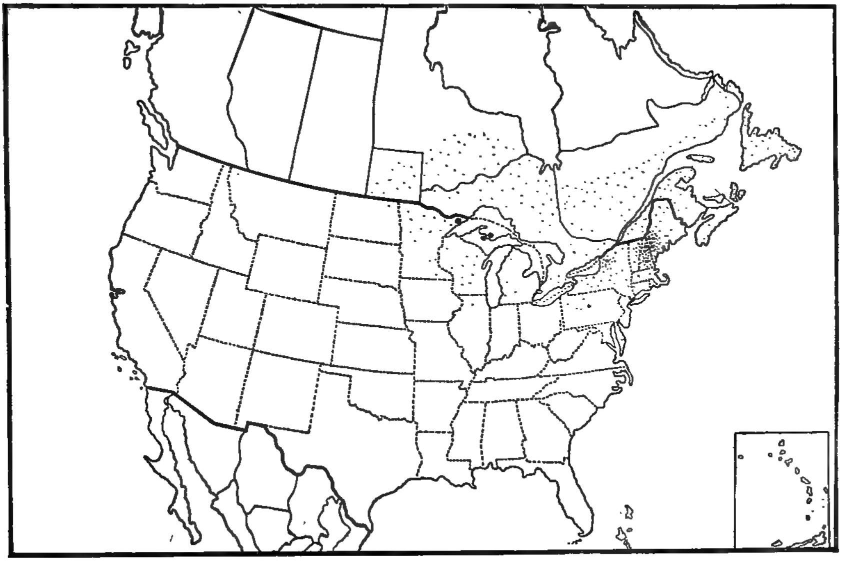

FIG. 77.—The eastern spruce beetle: Distribution map. (Author's illustration.)

It is represented in the forest-insect collection of the Bureau of Entomology by more than 300 specimens.

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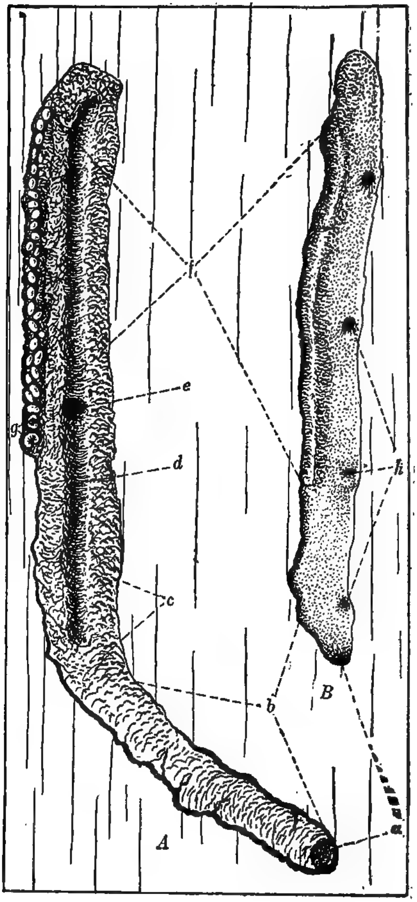

FIG. 78.—The Engelmann spruce beetle (*Dendroctonus engelmanni*): Egg gallery in living bark. *A*, Normal; *B*, boring dust removed; *a*, entrance; *b*, basal section; *c*, boring dust packed in gallery; *d*, subsequent or inner gallery; *e*, ventilating burrow; *f*, egg nest, with and without eggs; *g*, freshly hatched larvæ; *h*, pits in roof of gallery. (Author's illustration.)

No. 15. THE ENGELMANN SPRUCE BEETLE.

(*Dendroctonus engelmanni* Hopk. Figs. 78–82.)

The Engelmann spruce beetle is a reddish-brown to black barkbeetle, 5 to 7 mm. in length, with body sparsely clothed with long hairs, head broad and convex, prothorax sometimes darker than the elytra and with sides of pronotum distinctly narrowed and constricted toward the head and the punctures of irregular size and distinctly coarse, the elytra with coarse rugosities between rows of indistinct but coarse punctures, and the declivity convex and somewhat flattened. It attacks the Engelmann spruce, and probably other spruces, from central Idaho southward to the mountains of southern New Mexico, and the white spruce in the Black Hills of South Dakota. The galleries are similar to those of the eastern spruce beetle.

SEASONAL HISTORY

OVERWINTERING STAGES.

The broods of this beetle pass the winter in all stages of larvæ and as adults in the inner bark of trees attacked by the parent beetles during the preceding summer.

ACTIVITY OF OVERWINTERED BROODS.

The adults begin to emerge from the bark and fly during May or June. They settle on felled or standing injured or on healthy trees and enter the living bark to deposit eggs (see fig. 78), which soon hatch into larvæ. The broods of larvæ feed in the inner bark and destroy that portion of it intervening between the egg galleries, and thus completely girdle and cause the death of the trees which were healthy when attacked. The medium to larger matured trees are the ones commonly selected by the beetle, and it is capable of killing all such timber within a forest.

In the Black Hills of South Dakota, at an altitude of about 5,000 feet, Mr. Webb found an adult flying on June 10. On July 30 adults were excavating galleries and depositing eggs, which hatched and had developed into nearly fullgrown larvæ on October 14. It would appear, therefore, that the adults of this species come out a little earlier than those of the eastern spruce beetle.

ECONOMIC FEATURES.

This species, like the eastern spruce beetle, attacks only the larger or mature trees. It is evidently the most important enemy of the Rocky Mountain spruces, and from time to time has caused widespread destruction.

In October, 1905, the writer found evidence of its destructive work (see figs. 79, 80) in the Pike National Forest, caused many years ago. At the time the observations were made the indications were that the vast destruction of spruce in this reserve heretofore attributed to fire was primarily caused by this beetle. This was particularly evident on the southern slopes of Pikes Peak, at an altitude of about 10,000 feet, where nearly all of the timber had been killed some fifty years ago. In the fragmentary patches of living timber, old felled trunks of a primitive matured forest of Engelmann spruce were found thickly covering the ground. On the weather-beaten surface of these logs the characteristic markings of the galleries of this beetle were so common as to leave little doubt that the trees had been killed during a destructive invasion by it—indeed, very conclusive evidence of this was found in the presence of dried resin in the egg-gallery grooves and on the surface of the wood, which would not be found there if the trees had been attacked after they were dying from other causes.

This additional evidence, together with the known devastating work of this class of insects, makes it clear to the writer that there has been a most intimate interrelation of destructive barkbeetles and forest fires in the denudation of the vast areas of once heavily forested lands in the Rocky Mountain region, and that in very many cases the insects have first killed the timber, and the fire has then followed (see fig. 81), leaving the charred trunks and logs as apparent proof that the fire alone was responsible.

In August, 1905, Supervisor A. W. Jensen, of the Manti National Forest, Utah, reported much destructive work by a beetle which proved to be this species. He stated that in some sections 20 per cent was then attacked or killed, including both the Engelmann spruce and the blue spruce.

In August, 1906, Mr. Harry Gibler reported that all of the matured Engelmann spruce of the White River National Forest, in Colorado, was more or less affected by a beetle which the writer identified as this species. In response to a request for more detailed information, Mr. Gibler, in a letter dated November 13, 1906, wrote as follows:

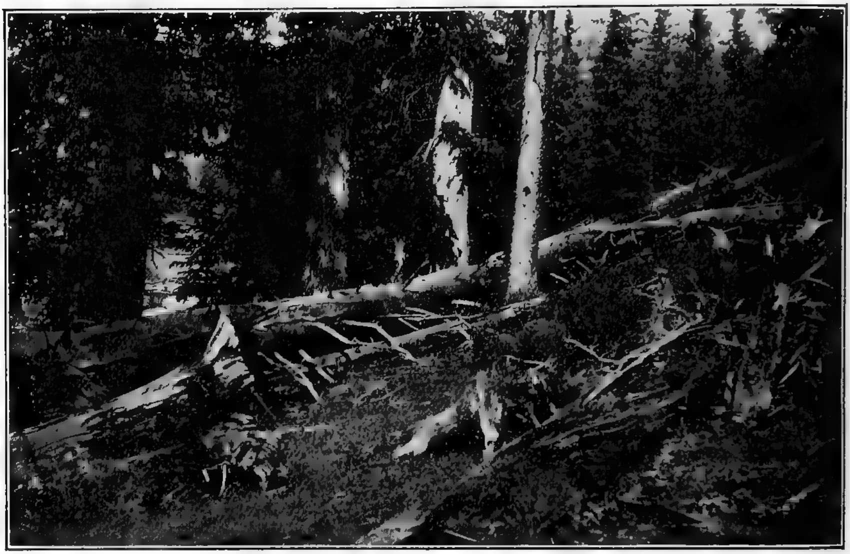

FIG. 79.—Engelmann spruce evidently killed by Engelmann spruce beetle about 1853-6; pitch-marked galleries common on trunk. Pike National Forest, at elevation of about 10,000 feet. (Original.)

> There is no portion of the reserve on which they are especially active, but are more or less over the entire area. In some places as much as 90 per cent of the mature timber is already dead and in some localities as little as 2 per cent seems to be affected, and in this connection I would state that so far the oldest trees, and that which is classed as strictly mature timber, have been affected.

In the Twentieth Annual Report of the United States Geological Survey, p. 137, Mr. G. B. Sudworth states:

> There is a considerable quantity of dead standing spruce mingled with the green timber. It extends in an interrupted irregular narrow belt from the region of Deep Lake and Carbonate westward to the headwaters of East Elk Creek. The dead tim-

ber amounts to from 10 to 25 per cent of the total stand and includes nearly, or quite, all the largest and oldest trees. They bear evidence of having died about twenty to twenty-five years ago.

Mr. W. D. Edmonston inspected this timber on September 23–24, 1907, and reported to the writer as follows:

> I don't know where Mr. Sudworth observed the old and dead spruce; but I was with Supervisor Blair when he was estimating for a sale of Engelmann and Alpine fir (September 23, 24, 1907) in Bear Park, near Dale's sawmill, 12 miles northeast of New Castle, and we found all through this body of timber that the dead Engelmann, all over 15 inches in diameter, amounted to 25 per cent. I examined this dead timber most carefully. I spent the entire day examining the trees, while Mr. Blair and two of his rangers were estimating. I did not find one single Engelmann that had died within the past twenty-five years that had not been beetle-killed, the galleries of the Engelmann spruce beetle showing plainly on the trunk. I pointed out hundreds of such trees to Mr. Blair and the rangers. But I failed to find any new work. This timber must have been killed about twenty years ago, if not longer. Old snags, standing and down, all showed plainly the yellow-stained galleries, just like those you pointed out to me the day we were at Clyde, on the road to Seven Lakes, in the Pikes Peak, and just the same as that on the specimen I sent you from near Crested Butte, Gunnison National Forest.

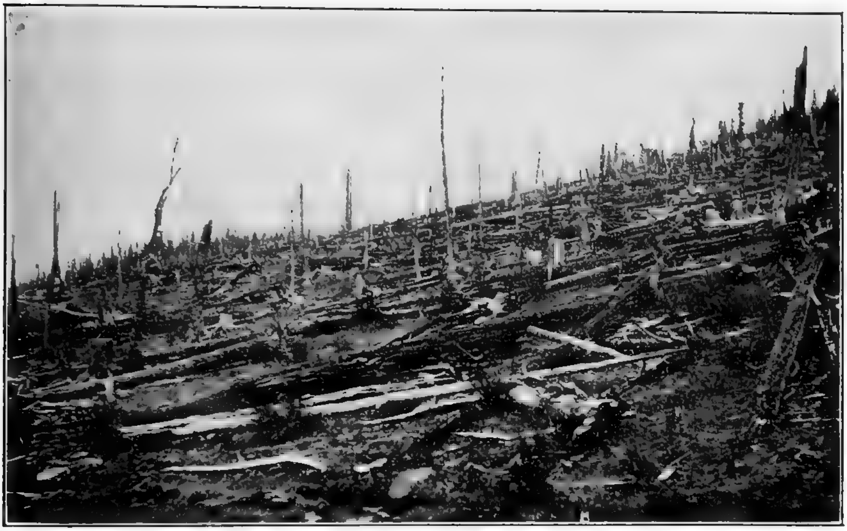

FIG. 80.—Engelmann spruce timber evidently killed by Engelmann spruce beetle and subsequently partially burned by fire. Pike National Forest, at elevation of about 10,000 feet. (Original.)

On January 10, 1908, Mr. W. D. Edmonston reported that the large stands of Engelmann spruce in the White River National Forest showed an average of 20 per cent beetle-killed throughout.

In March, 1907, Mr. Frank J. Phillips, forest assistant, of the Forest Service, in a report on conditions in the Lincoln National Forest, New Mexico, refers to a forest fire of doubtful date, 1892 to 1895, which it is claimed killed and weakened portions of the spruce stand aggregating approximately 1,200 acres, although it is probable that the insect was present before the fire occurred. He states as follows:

> Two or three years after the fire serious work of the insect was first made apparent, and local observers state that the beetle work has steadily increased until the entire spruce stand is threatened with insect destruction. In his 1904 report Mr. F. G. Plummer stated, "Notwithstanding the fact that the summits of the Sierra Blanca afford apparently ideal conditions for the growth of the spruce, about 20 per cent of the standing trees are dead or dying. This gives the forest the appearance of having been scorched by a fire not severe enough to utterly destroy it. For this no cause was found.
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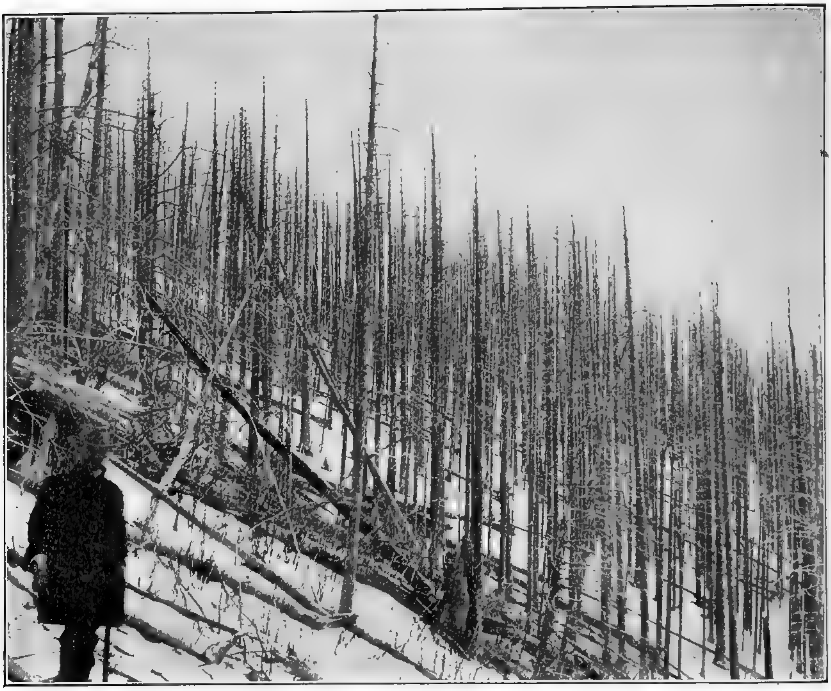

Fig. 81.—Average-sized Engelmann spruce killed by fire and the Engelmann spruce beetle. Lincoln National Forest, at elevation of 10,150 feet. (Original.)

> The insect work occurs at an elevation above 9,000 feet and will probably extend to the altitudinal limit of the spruce in case it has not already done so. It was found in trees varying from 6 to 20 inches, which had not been subject to other injury. Approximately 1,000 acres of the headwaters of the South Fork of the Rio Bonito have been completely killed by the combined effect of fire and insects, and other similar areas exist in the reserve.

Mr. F. G. Plummer, of the Forest Service, in a report entitled "Forest conditions in the Lincoln National Forest, New Mexico"[a] estimates a total stand of 29,027,000 feet, board measure, on 13,142 acres. Of this, 1,480 acres, or about 9 per cent, has been burned.

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[a] Professional Paper No. 33, series H, Forestry, 11, U. S. Geological Survey.

Mr. W. F. Fiske, of this Bureau, who was sent to investigate the conditions as to insect ravages in the White Mountains of the Lincoln National Forest, reported that during his investigations in May, 1907, he found that at least 95 per cent of all of the Engelmann spruce outside of the burned areas was beetle-killed, but that practically all of this was rather old work and that there was very little evidence of the beetles' presence at that time.

Mr. J. L. Webb, of this Bureau, visited the same area in September and estimated that fire had killed about 15 per cent of the total stand of spruce, and that the beetle has killed about 90 per cent of the remainder.

METHODS OF CONTROL.

The methods of controlling this beetle are essentially the same as for the eastern spruce beetle.

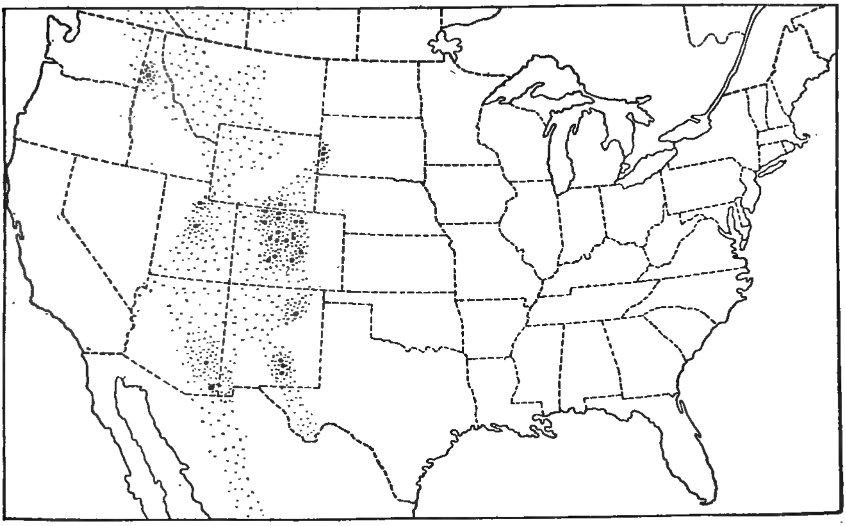


FIG. 82.—The Engelmann spruce beetle: Distribution map. (Author's illustration.)

BASIS OF INFORMATION.

Information concerning this barkbeetle is based on investigations by the writer at Boulder, Colo., August, 1901; at Black Hills, S. Dak., September, 1901, and August, 1902, and in the Pike National Forest, Colo., October, 1905; by Mr. J. L. Webb, at Collins, Idaho, September, 1900; in the Black Hills, S. Dak., June and October, 1902, and August, 1906; in the Rincon Mountains, Ariz., and in the Capitan Mountains and at Cloudcroft, N. Mex., from May to September, 1907; by Mr. W. F. Fiske, in the Capitan Mountains, N. Mex., May, 1907; by Mr. W. D. Edmonston, in the Ouray National Forest, at Craig, Steamboat Springs, and Hahns Peak, in the White River

National Forest, and in the Holy Cross National Forest, Colo., and at Encampment, Wyo., in 1907. Additional localities through correspondence and from collections are: Ephraim and Alta, Utah; Meeker, Silver Plume, Argentine, Glenwood Springs, and Leadville, Colo.; Capitan, Lincoln National Forest, and Las Vegas, N. Mex.; Calgary, Alberta Province, and Glacier, British Columbia. It is represented in the forest-insect collection of the Bureau of Entomology by more than 200 specimens.

BIBLIOGRAPHY.

Packard, 1877 (under *Dendroctonus obesus*), p. 803; Hopkins, 1906*a* (under *D. piceaperda*), pp. 4–5; Hopkins, 1907 (under "The Engelmann spruce beetle"), pp. 161–162; Hopkins, 1909, pp. 130–133.

No. 16. THE ALASKA SPRUCE BEETLE.

(*Dendroctonus borealis* Hopk. Figs. 83, 84.)

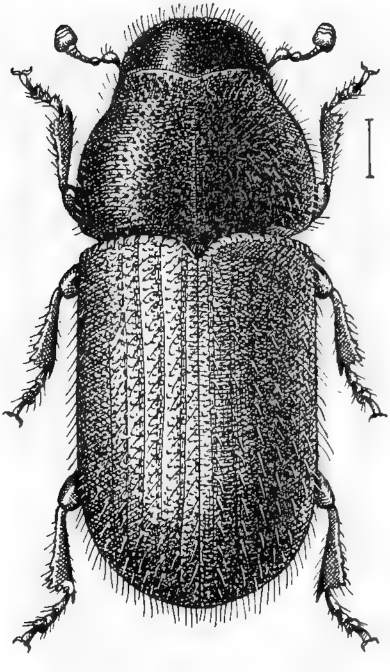


FIG. 83.—The Alaska spruce beetle (*Dendroctonus borealis*): Adult. Greatly enlarged. (Author's illustration.)

The Alaska spruce beetle resembles closely in general characters the eastern spruce beetle, but is smaller, and is distinguished by the coarser punctures of the pronotum being more regular in size. (See fig. 83.)

This species is represented in the collections by but four specimens, two in the United States National Museum collection, labeled "Alaska," and two in the forest-insect collection of the Bureau of Entomology, collected by Mr. W. H. Osgood from white spruce at Eagle, Alaska, in August, 1903. Nothing further is known about this species, but it will probably be found that its habits and life history are similar to those of Nos. 14 and 15.

BIBLIOGRAPHY.

Hopkins, 1909, pp. 133–135.

No. 17. THE SITKA SPRUCE BEETLE.

(*Dendroctonus obesus* Mann. Figs. 85, 86.)

The Sitka spruce beetle is a large, stout, black, cylindrical bark-beetle 6 to 7 mm. in length, with broad convex head, the sides of pronotum narrowed and constricted toward the head, and surface punctured with irregular large and small punctures, the elytra with moderately coarse rugosities between moderately distinct rows of punctures, and the declivity not strongly convex and nearly smooth, shining in the male, more dull and roughened in the female. The entire body is sparsely clothed with long hairs. (See fig. 85.) It attacks the living bark on the trunks of living, dying, and newly felled trees, stumps, and large branches of Sitka spruce, from Newport, Oregon, northward along the coast to Alaska, probably following the distribution of the tree in which it lives. The general character of attack and of egg and larval mines is practically the same as described under *D. piceaperda*, except that the larval mines are perhaps more generally connected toward the egg gallery and that the pupal cases are sometimes grooved in the wood, while others are concealed in the outer portion of the inner bark.

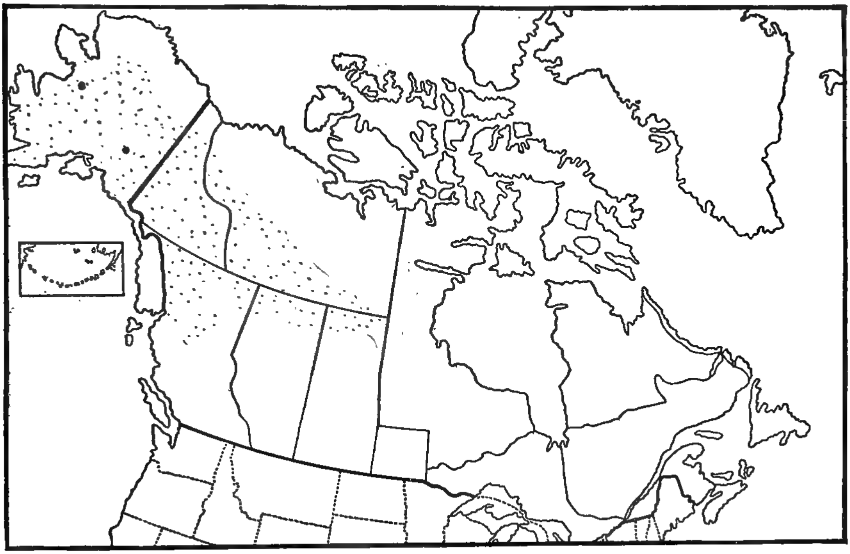


FIG. 84.—The Alaska spruce beetle: Distribution map. (Author's illustration.)

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed principally as adults and matured larvæ in the inner bark on trees, logs, and stumps where they developed the preceding summer.

ACTIVITY OF OVERWINTERED BROODS.

Activity of the overwintered broods begins in April. The adults begin to emerge about the middle of April, and continue to come out as the broods of overwintered larvæ develop, probably until the 1st of July, but the principal period of emergence is during May and June.

GENERATION.

The adults begin to attack the trees, excavate galleries, and deposit eggs early in May, and continue to do so through June, probably until August, though the principal period is in May and June. Fresh attacks and eggs are also found in September, either by adults of overwintered broods or those developed from eggs deposited early in the spring. The larvæ begin to hatch in May, and probably continue hatching until in August, but the principal period is in June and July. The principal period of larval development is during June, July, and August. The larvæ begin transforming to pupæ toward the last of July, and continue transforming probably until winter, but the principal period is in August and September. The pupæ begin to transform to adults probably during the second week in August, and continue transforming until winter. The principal period of transformation to adults is during the month of September. The period required for the development from eggs to adults is about three months.

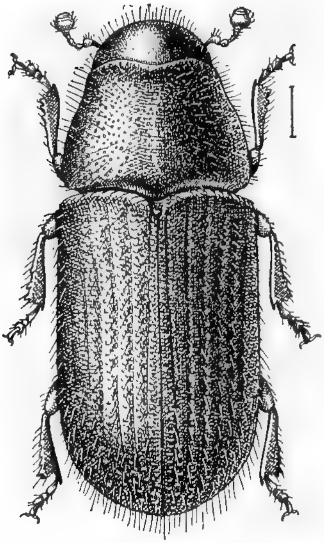


FIG. 85.—The Sitka spruce beetle (*Dendroctonus obesus*): Adult. Greatly enlarged. (Author's illustration.)

The more advanced broods of the generation complete their development by the last part of August and first part of September, while the later ones evidently pass the winter as mature larvæ and immature adults, to complete their development the following spring. There is, therefore, one complete generation during the year.

The fact that eggs and young larvæ are common in September indicates that some of the broods of the first generation may emerge in the fall and deposit eggs from which there is a partial second generation, but it is not improbable that some of the parent beetles of the overwintered broods may leave the trees after they have completed the first set of galleries, and excavate galleries in the same or other trees. If there is a partial second generation the brood passes the winter in the larval stage, possibly together with the parent beetles.

HABITS.

This species appears to prefer to attack the living bark on the trunks and stumps of felled trees and on the trunks of those still standing but weakened and injured. Apparently it will not attack healthy trees when there are plenty of felled and injured ones for it to infest. So far as observed it attacks only the Sitka spruce, but it is probable that it will be found in the Engelmann and white spruces, if they grow in the vicinity of the Sitka spruce.

The gallery is very much the same as those of the eastern spruce beetle and the Engelmann spruce beetle, except that the larval mines appear to be even more generally connected toward the egg gallery. The larvæ and pupæ are either exposed or hidden in the inner bark, and the pupal cells are sometimes grooved in the surface of the wood. Sufficient observations have been made on the flight of this species to indicate that it flies during the day, and even in bright sunshine.

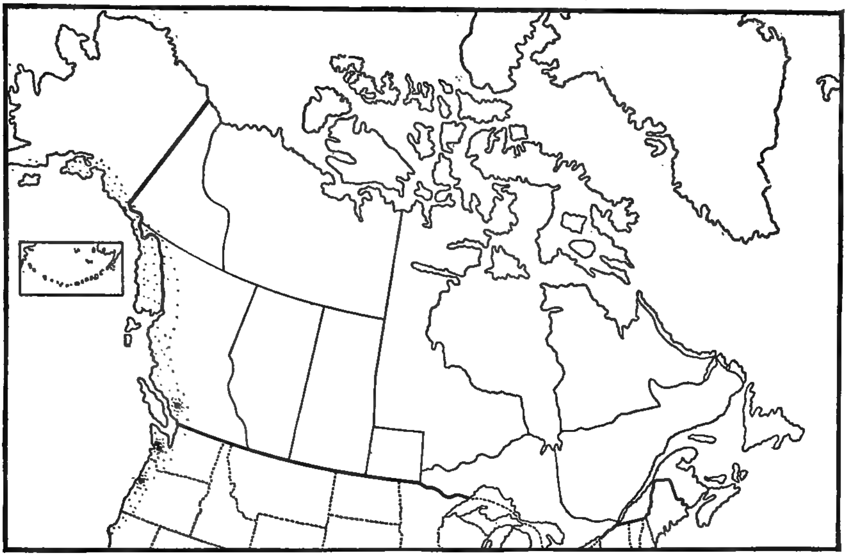


FIG. 86.—The Sitka spruce beetle: Distribution map. (Author's illustration.)

ECONOMIC FEATURES.

So far as observed, this species has not been found attacking healthy trees in sufficient numbers to cause their death, but it is not improbable that under specially favorable conditions for the increase of its broods the older living timber might be attacked and killed as it is by the eastern spruce beetle. If so, the evidence of attack would be similar to that described under Nos. 14 and 15.

METHODS OF CONTROL.

If this barkbeetle should be found killing trees, the method of control would be similar to that recommended under the eastern spruce beetle, except that summer operations of barking or utilizing the infested trees during June, July, and August would be less objectionable. As a rule, however, winter operations would be preferable, the work to be completed before the 1st of April.

BASIS OF INFORMATION.

Information regarding this species is based on investigations by the writer at Newport, Oreg., April, 1899, and at Hoquiam, Wash., May, 1903; by Mr. H. E. Burke at Aberdeen and Hoquiam, Wash., April to June, 1903, and August, 1903, at Hoquiam and Aberdeen, Wash., May to September, 1904, and at Hoquiam May and June, 1905. Additional localities from correspondence and other collections are Queen Charlotte Islands and Vancouver, B. C. It is represented in the forest-insect collection of the Bureau of Entomology by more than 120 specimens.

BIBLIOGRAPHY.

Hopkins, 1899*b* (under *Dendroctonus similis* and sp. near *D. rufipennis*), pp. 15, 21; Hopkins, 1902*c*, p. 22; Hopkins, 1903*a*, p. 60; Hopkins, 1904 (under *D. obesus*), p. 19; Hopkins, 1909, pp. 135–138.

No. 18. THE REDWINGED PINE BEETLE.

(*Dendroctonus rufipennis* Kirby. Figs. 87, *A*, 88.)

The redwinged pine beetle (fig. 87, *A*) is a stout, cylindrical barkbeetle, with reddish elytra and dark-brown or black prothorax, 5 to

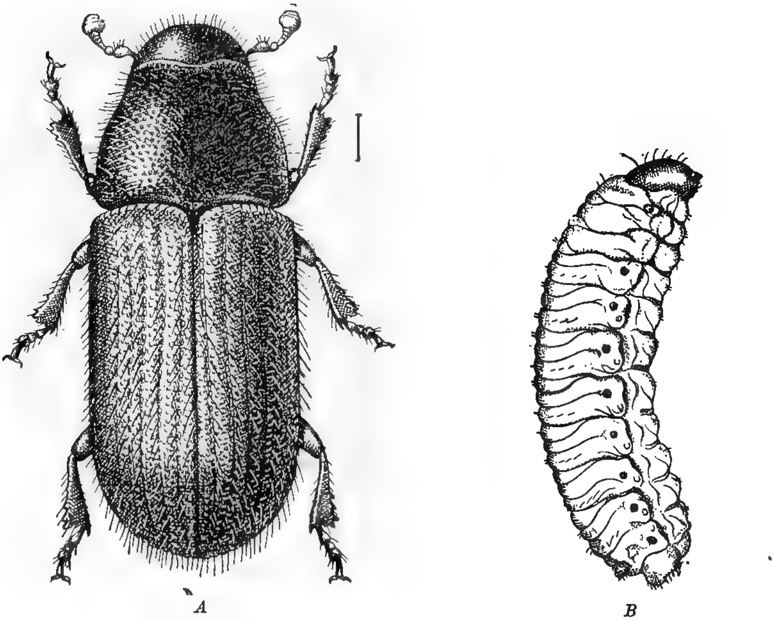


FIG. 87.—*A*, The redwinged pine beetle (*Dendroctonus rufipennis*), adult, greatly enlarged; *B*, the lodgepole pine beetle (*Dendroctonus murrayanæ*), larva, less enlarged. (Author's illustrations.)

7.5 mm. in length, with the head broad and convex; the prothorax slightly narrower than elytra, its sides narrowed and slightly constricted toward the head, the surface even and shining, with coarse and small punctures intermixed; the elytra with moderately coarse rugosities between rows of moderately coarse and but slightly impressed rows of punctures, and the declivity smooth and shining in the female and less shining and more rugose in the male. It attacks felled white pine in northwestern Michigan. The primary or egg gallery is evidently of the same character as those of the spruce beetles, but the larval mines are probably like those of the European spruce beetle and the black and red turpentine beetles of this country. The larvæ resemble those of the eastern spruce beetle in the dorsal plates on the last two abdominal segments, but are distinguished by a row of brown spots (spiracles) on each side of the body, as in figure 87, *B*.

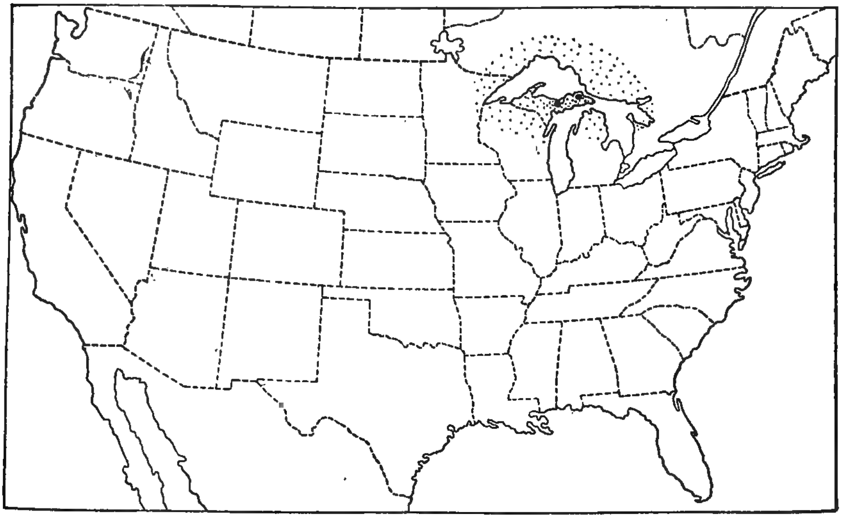


FIG. 88.—The redwinged pine beetle: Distribution map. (Author's illustration.)

SEASONAL HISTORY.

This species evidently passes the winter in the adult and larval stages. Fully developed broods and larvæ were found by Mr. W. F. Fiske, October 20, at Grand Island, Mich. Nothing further is known of the life history, but it is probable that it will not differ materially from that of the eastern spruce beetle.

HABITS.

Mr. Fiske found the developed broods under the bark on the underside of the trunk of a storm-felled white pine some distance from the base. Nothing further is known of the habits of this species, although it was one of the first species of the genus to be described from North America.

BASIS OF INFORMATION.

Information about this species is based on investigations by Mr. W. F. Fiske, on Grand Island, Mich., October, 1906. An additional locality from the collection of the United States National Museum is Whitefish Point, Mich. The species is represented in the forest-insect collection of the Bureau of Entomology by 14 specimens.

BIBLIOGRAPHY.

Hopkins, 1901*a*, p. 16; Hopkins, 1902*b*, p. 10, footnote; Hopkins, 1909, pp. 138–140.

No. 19. THE LODGEPOLE PINE BEETLE.

(*Dendroctonus murrayanæ* Hopk. Figs. 87, *B*, 89.)

The lodgepole pine beetle is a stout, cylindrical barkbeetle, 5.4 to 6.5 mm. in length, with reddish elytra and dark-brown or black prothorax; the head broad, convex; the pronotum slightly narrower than the elytra, its sides narrowed and constricted toward the head, the punctures coarser and less uneven sizes than in No. 18, and the elytra with rows of coarse, shallow punctures. It attacks lodgepole pine in southern Wyoming and occurs northward to Alberta, B. C. The egg gallery is like that of the eastern spruce beetle, but the larval mines are more like those of the European spruce beetle. Adults were found excavating galleries and depositing eggs July 31, at Saratoga, Wyo. (Medicine Bow National Forest), in young living lodgepole pine, by Mr. Jeremiah Rebmann, of the Forest Service. On October 12 parent adults and half-grown larvæ were found in the same tree.

HABITS.

According to Mr. Rebmann's observations, the species attacks living trees toward the base, excavates galleries as much as 18 inches in length, with large pitch tubes at the entrance, and deposits the eggs along one side, partitioned off with boring dust. The same trees were thickly infested with the Oregon Tomicus; therefore it was not determined whether the Dendroctonus or the Tomicus made the first attack. The fact, however, that there were large pitch tubes indicated that the primary attack was made by this species, although many other trees were found infested and killed by the mountain pine beetle. The work of the lodgepole pine beetle was observed in but a few trees.

Fragmentary specimens of a beetle identified as this species were received in August, 1905, through the Forest Service, from Mr.

W. E. Jackson, with the statement that the beetle was doing considerable damage in the Big Horn National Forest, Wyo.

Nothing further is known of the habits of this species.

BASIS OF INFORMATION.

Information about this species is based on specimens and notes received from Forest Assistant Jeremiah Rebmann, of the Forest Service, July, August, and October, 1905, collected in the Medicine Bow National Forest, Wyo., and through the Forest Service from W. E. Jackson, Big Horn National Forest, Wyo.; on investigations by Mr. W. D. Edmonston, in the Pike National Forest (Jefferson), Colo., December, 1906; on specimens received through the Forest Service from the Cheyenne National Forest, September, 1908. Additional localities from correspondence and other collections are, Saratoga, Yellowstone National Park, and Homestake, Wyo. It is represented in the forest-insect collection of the Bureau of Entomology by more than 100 specimens.

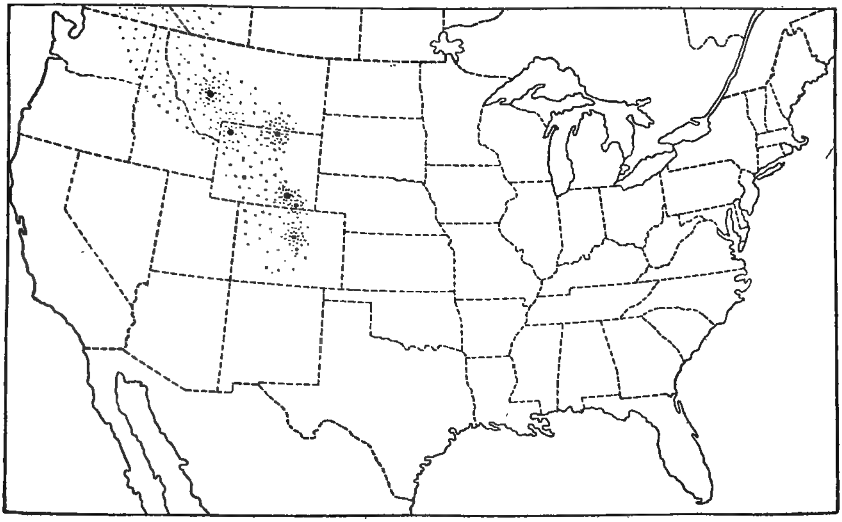


FIG. 89.—The lodgepole pine beetle: Distribution map. (Author's illustration.)

BIBLIOGRAPHY.

Hopkins, 1909, pp. 140–142.

No. 20. THE ALLEGHENY SPRUCE BEETLE.

(*Dendroctonus punctatus* Lec. Figs. 90, 91.)

The Allegheny spruce beetle is a stout, brownish, cylindrical bark-beetle, 6.5 mm. in length, resembling *D. piceaperda*, but larger, with distinctly longer elytra in proportion to the thorax; head broad, shining; thorax slightly narrower than elytra, with sides distinctly narrowed toward the head, the surface with coarse and fine punctures; elytra elongate, with coarse rugosities between rows of indistinct coarse punctures, the punctures on the sides of the elytra very coarse; the declivity with rows of coarse, distinct punctures, and the body sparsely clothed with long hairs. (See fig. 90.)

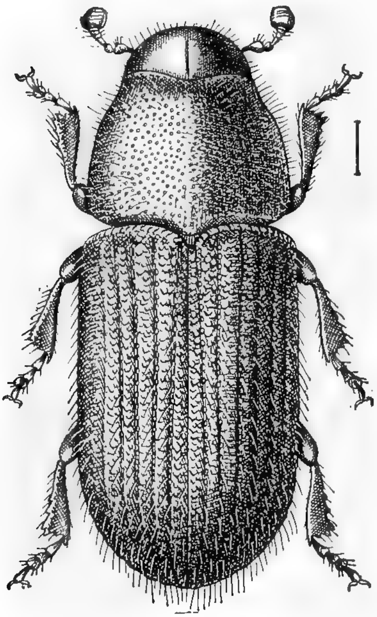


FIG. 90.—The Allegheny spruce beetle (*Dendroctonus punctatus*): Adult. Greatly enlarged. (Author's illustration.)

BASIS OF INFORMATION.

One specimen of this species was taken by the writer in the higher mountains of Randolph County, W. Va., May 21, 1893, from a freshly excavated gallery in the bark of the stump of a red spruce tree felled during the previous winter. This appears to be all that is known of its habits.

It is represented in the Le Conte collection by two specimens from New York, from which descriptions were made in 1868, and by one specimen from Pennsylvania in the collection of the Academy of Natural Sciences, Philadelphia, Pa. Therefore, so far as known, its

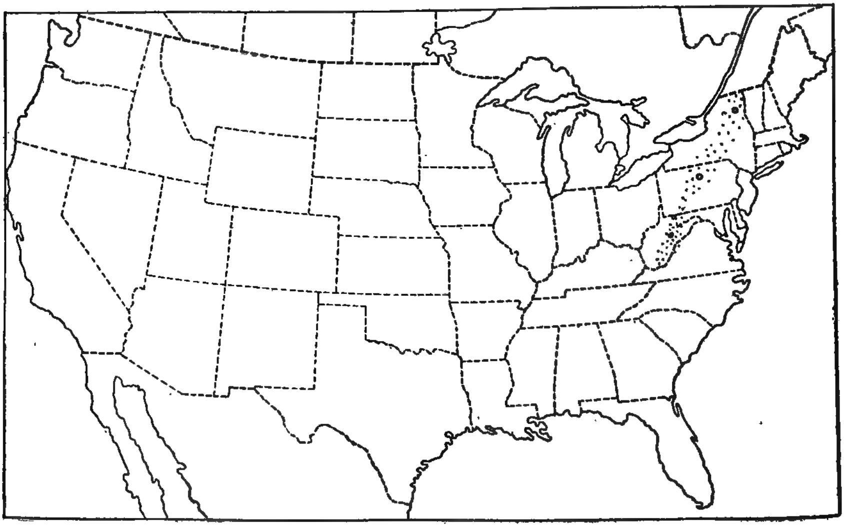


FIG. 91.—The Allegheny spruce beetle: Distribution map. (Author's illustration.)

distribution is confined to the region of the mountains of West Virginia and northward to northern New York.

This species comes nearer to the European spruce beetle than it does to any of the other species, and therefore will probably have similar seasonal history and habits.

BIBLIOGRAPHY.

Hopkins, 1899*a*, p. 447; Hopkins, 1909, pp. 142–143.

No. 21. THE EUROPEAN SPRUCE BEETLE.

(*Dendroctonus micans* Kug. Figs. 92–94.)

The European spruce beetle is a large, stout, reddish-brown, cylindrical barkbeetle, 7 to 8 mm. in length, with broad, convex head; short prothorax, with sides of pronotum distinctly narrowed and constricted toward head; elytra somewhat shining, with moderately coarse rugosities between rows of rather distinct punctures, and the declivity smooth and more shiny in the males than in the females. (See fig. 92.) According to European writers, it attacks the living bark, usually at the base of injured, dying, and living trees and stumps of felled spruce, pine, fir, and larch, from central to northern Europe and in Denmark, Russia, and eastern Siberia.

HABITS AND SEASONAL HISTORY.

It is said that the broods pass the winter in the mines in the bark as parent adults, young adults, and all stages of larvæ. The young adults emerge in June and excavate long, irregular egg galleries (fig. 93), usually in the bark at the base of stumps and trees, sometimes extending into the roots, but sometimes at various points on the trunk, even to and among the branches. The female deposits from one hundred to one hundred and fifty eggs in groups of from thirty to fifty, and the larvæ proceed in a body to excavate broad brood chambers (fig. 93), very much in the same manner as with the black and red turpentine beetles.

The broods hatching from eggs deposited in May and June by the overwintered adults develop into pupæ and adults by September, or later, but remain in the brood galleries until the next spring. The broods developing from overwintered young larvæ transform to pupæ and adults in June and July, emerge and deposit eggs in July and August, or later, and pass the winter in different stages, as young to matured larvæ.

ECONOMIC FEATURES.

It is said that this species prefers to attack the bark on the base of the trunks and roots of sound or healthy trees, and that the connecting of the broad larval chambers from the same egg gallery or from several galleries has the effect of girdling the tree, either causing its death or a weakened condition which attracts other barkbeetles to complete the destruction. Young as well as old trees are attacked, but, while this species will breed in standing injured or weakened trees, it rarely breeds in felled ones. It apparently prefers the spruces, but will, according to different authors, attack pine, fir, and larch.

The evidences of attack are masses of gum or resin and so-called pitch tubes, mixed with reddish boring dust.

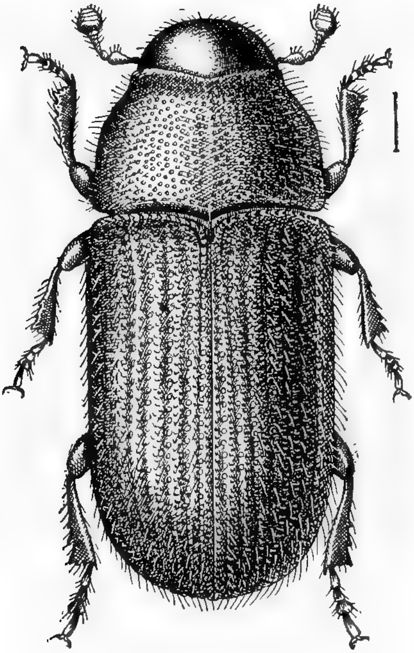


FIG. 92.—The European spruce beetle (*Dendroctonus micans*): Adult. Greatly enlarged. (Author's illustration.)

METHODS OF CONTROL.

Removing the bark from the infested trunk and roots, or scorching it if not removed, is recommended to kill the broods. Coating the trunks of the trees with a preparation of tobacco water, Spanish blood, lime, fresh cow dung, etc., is recommended as a preventive.

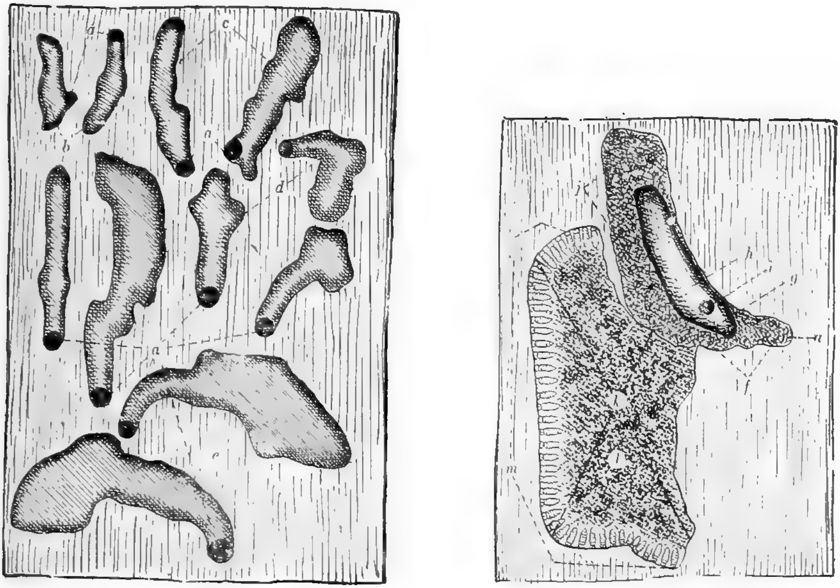
After the above was written the writer received a paper on the genus Dendroctonus from Dr. G. Severin (1908), director of the Royal Museum of Natural History of Belgium. A large series of specimens of the beetle and its work was also received from Doctor Severin, which was of special value and interest. Doctor Severin's paper covers the more important historic and economic information on the species recorded in European literature to 1908. Some of the information in the paper that is of special interest in connection with a discussion of all of the species is summarized as follows:

INFORMATION FROM PAPER ON THE GENUS DENDROCTONUS, BY DR. G. SEVERIN (1908, pp. 1-20).

Dendroctonus micans alone, of all the hylesinids, and perhaps of all the scolytids, appears to love the resin and to live there with ease. It neglects the weak trees and is found principally upon trees full of vigor, of an age of 30 years and more, where it lives in the middle of pockets full of resin. During the larval period *micans* conducts itself differently from other Belgian hylesinids in that each larva does not make a separate gallery, but all work together, making one common wide gallery. The egg-laying extends sometimes over several months. This results in a parallel development of larvæ, pupæ, and adults, which are to be found thus during the greater part of the year.

The excavation of the gallery begins the last of May or the first of June.

The attack of the insect, which traverses the bark to reach the sapwood, causes each time an abundant flowing of resin mixed with sawdust and excrement, which gives it a brownish color, sometimes violaceous. This resin often forms nipplelike blocks, sometimes 30 mm. high by 25 mm. in diameter, which dry and harden in the air and finish by crumbling. The particles fall at the foot of the tree, among the needles forming the ground cover, often being in a very considerable number, resembling the dried lumps of mortar at the foot of a freshly constructed wall, following the excellent comparison of Altum.



A B

FIG. 93.—The European spruce beetle. Egg galleries and larval chamber: *A*, Basal sections of egg galleries; *B*, advanced stage of work; *a*, entrance burrow; *b*, excavated July 8–16; *c*, excavated July 8–29; *d*, eight days old; *e*, three weeks old; *f*, basal section; *g*, boring dust; *h*, subsequent or inner gallery ("mother gallery"); *j*, egg nest with eggs scattered about in boring dust; *k*, social chamber excavated by larvæ; *l*, boring dust and resin; *m*, larvæ at work. (Adapted from Pauly, Forstlich-naturwissenschaftliche Zeitschrift, I Jahrgang, figs. 3 and 4.)

The egg gallery is vertical, frequently curved and somewhat irregular, sometimes doubly inflected, having 12 to 20 cm. of length. The female here deposits from 20 to 25 eggs several times. Following this she quits this place, to commence upon another point of the same tree or upon neighboring trees, even to the deposition of from 150 to 200 eggs. Sometimes she is found dead in a final gallery having deposited but a few eggs, the rest of her provision.

The egg laying is done slowly after this preparatory work. It is therefore easily understood that a female which has deposited her first eggs about the month of June sometimes goes to the month of September before having finished the operation. It transpires, perhaps, that the mother hibernates and finishes the evacuation of her eggs at the commencement of the following year.

The larvæ eat very close together, growing equally in size and age and making a common cavity underneath the bark. These larvæ are white and resemble those of Pissodes or the young larvæ of Hylobius. In order to go through the pupal stage, they return to the large space which they left behind them and which is filled with excrement agglutinated by resin. It is there that they construct their pupal cases, unless, departing from their common cavity, they eat out isolated galleries at the end of which the pupal cases are formed. Here they hibernate also and the perfect adults here find their chamber of hibernation, although they approach a little nearer the place of entrance.

It is apparent from the preceding that an egg laying extending often over several months produces evolutionary cycles very different from each other as long as it lasts.

If the larvæ which pass over the winter can find a sufficient quantity of heat for their complete evolution, they go on to the pupal and adult stages. Others will be found later which will not be able to terminate their larval stage before the weather turns cold again and will be obliged to hibernate in their cells made in the middle of the dried excrement. Between these two extreme cases one finds intermediate stages, possibly, for example, some in the pupal state.

A hatching taking place toward the middle of this favorable period would not permit them, therefore, to attain their growth before winter.

In winter the adult secretes itself most often in wounds on the tree, where the larval state has been passed, or else it eats out small galleries between the roots and even under the bark, underneath the level of the ground.

This giant hylesinid lives almost entirely in spruce. The trees on the outskirts of a planting, south and east, so that they are more exposed to the rays of the sun, are the most menaced. As I have already said, the spruces from 25 to 50 years old are the most often attacked, but the old plantings from 60 years and more are not immune.

Micans should be counted among the insects very destructive to spruce. If the first attack does not kill the tree, it does not resist the attacks of the following generation which girdle the trunk by wounds and take all the natural adhesion between the bark and sapwood away. In this case the upper part of the trunk dies rapidly. When attack is made upon the roots the tree continues to live, at least while there are not a great many wounds upon several roots.

This insect was first introduced in forest entomology by Von Sierstorpf in 1794 under the name of *Bostrichus ligniperda*, but neither he nor Ratzeburg much later, and who did not repeat the statements made by Saxesen, believed that this insect was a serious enemy.

Stein, in 1852, did not believe it injurious, but two years later, in 1854, he had to modify his opinion, after great destructions of trees in the forests of Neudorf in Saxony, where *micans* attacked plantings from 40 to 50 years old, which had to be cut and sold on account of the attacks of insects.

Before 1858 the insect was almost unknown to Austrian entomologists. At that date Kollar speaks of a serious attack upon the spruces 100 years old in the Imperial Park of Laxenburg near Vienna, where *micans* had attacked in the beginning only some old trees which resisted for several years.

At the reunion of the Foresters' Society of Harz in 1867 communications upon the presence of *D. micans* came in from all sides. They had found it in Harz, in Thuringerwald, in Anhalt, and in the plains in the forestry district of Marienthal, near Brunswick, without meanwhile considering its presence a great nuisance.

In 1872 at the same assemblage Gebelers speaks of an attack at Thale in Harz, where *D. micans* had destroyed 10 hectares[a] of spruces mixed with sylvestral pines, all of them about 35 years old. Glück in 1876 cites a very strong attack in Rheinfalz near Coblenz. Since then the insect appeared everywhere and complaints arise every year in German forest literature. We know that the insect in its continual extension toward the west, after having seriously ravaged the plantings of Eiffel and of German Herzogenwald, has finished by reaching our frontier, and that it was discovered for the first time in Belgium in 1896 in Herzogenwald.

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[a] English equivalent, 24.71 acres.

It is quite clear that the preparation of trap trees in the sense that one understands them for the other scolytids can accomplish nothing.

The remedial measures in actual use are as follows: When the laborer going to his work in Herzogenwald, or the forest officer on his circuit, notices any of the characteristic signs of the attack of *D. micans* he does not fail to make known at once his discovery. In order to easily find the tree again he should attach around the trunk a belt of ferns or grass. At certain periods, several times during the dangerous months, later not so often, a worker, armed with a knife and a pruning knife, sometimes with a light ladder and a pail of coal tar or tar, makes the inspection of the contaminated region.

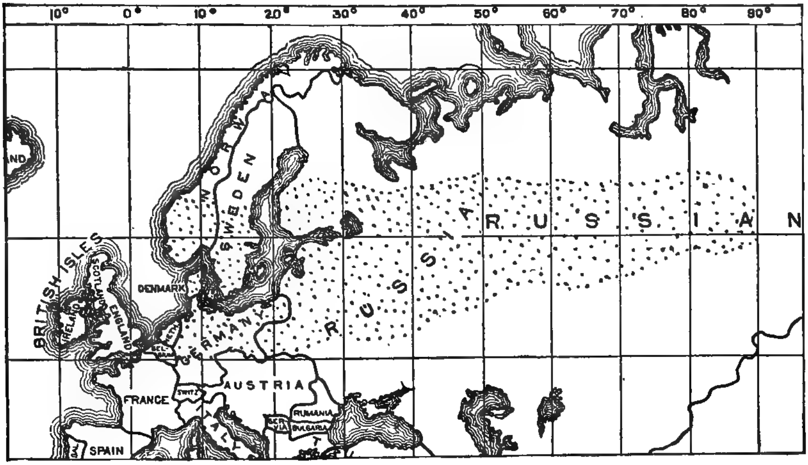

FIG. 94.—The European spruce beetle: Distribution map. (Author's illustration.)

After having encircled the tree with a special apron of twist, he raises the bark at the place of attack, cleans out the wound made by the larvæ, and re-covers it with the liquid preservative. The dried particles taken out are given to the fire and destroyed to the last particle, except during the months of summer, when the parasite, *Pimpla terebrans*, is to be found. When these are found it is necessary to examine the débris upon a sheet or cloth.

In order to clean out the wounds found upon the roots at their branching, a tool in the form of a recurved spade is used.

The expense resulting from such surveillance and the work of cleaning is not excessive when the attack is in its infancy and the trees attacked are not yet numerous.

Rarely it happens that the tree must be cut down.

It is not the same when the insect has been able to install itself in a planting for several years and to form serious breeding places. In order to avoid, then, making clearings in the middle of dense plantings, it is necessary to proceed with great prudence, to clear out with circumspection, and to sometimes clean the trees high and low when this is still possible. It is estimated that trees which are not attacked for more than two-thirds of the circumference of the trunk can in this extreme case be cleaned out and re-covered carefully with coal tar or tar.

It is evident that the price of cleaning becomes then very high; but we are compensated by preserving precious trees to continue the existence of the planting.

In conclusion, we counsel, therefore, repeated visits during the summer months in the forests where the presence of *D. micans* has already been determined and in those where it may be expected; then, visits less frequent during the months of spring and winter. We counsel, also, the assembling of all the official personnel of the forest service as soon as the presence of the insect is found and the giving of instruction as to the characteristic appearances attended by the insect attack. If necessary, a bounty might be paid.

After examining the trees designated, the foresters will decide whether it is best to cut down the trees or clean them.

In this manner it will be everywhere as in Herzogenwald, where a rigorous surveillance, but not at all expensive, has rendered the existence of the insect almost impossible.

SPECIMENS.

This species is represented in the forest-insect collection of the Bureau of Entomology by 90 specimens, including adults, larvæ, and work.

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No. 22. THE BLACK TURPENTINE BEETLE.

(*Dendroctonus terebrans* Oliv. Figs. 95, 96.)

The black turpentine beetle is a large, stout, dark-brown or black, cylindrical barkbeetle, 5 to 8 mm. in length, with broad prothorax, coarsely punctured pronotum, the sides slightly narrowed toward the head, but not strongly constricted; the elytra with coarse, transverse to oblique rugosities between distinct to obscure rows of punctures; the declivity convex, with moderately deep grooves, the intervening spaces slightly convex and roughened, and the entire body sparsely clothed with long hairs. (See fig. 95.) It attacks the living bark, usually at the base of injured, dying, or healthy trees, or the stumps of felled pine and spruce, from Long Island, N. Y., southward to Florida and westward to Texas and West Virginia, but it is more common in the South Atlantic and Gulf States. The parent beetles excavate broad, somewhat irregular, winding, longitudinal or sometimes transverse egg galleries through the inner bark and groove the surface of the wood. The eggs are placed in groups or masses at intervals along the sides of the galleries. The stout, yellowish-white, cylindrical larvæ, with reddish heads and stout spines on the dorsal plates of the last abdominal segments, do not make separate larval mines, but all feed together and eat out cavities in the inner bark from a few inches square to several feet square. They transform to pupæ and adults in separate or closely-joined cells in the inner bark or inner portion of the outer bark, but a few of the larvæ sometimes excavate independent mines beyond the social chamber for the purpose of pupating. The broods work independently of other species and occupy and separate the bark around the base of trees and stumps, often extending their work for a foot or more under the bark onto the roots beneath the surface. The broad larval chambers are often filled with semiliquid resin without injury to the occupants. The attack on living trees and on stumps of those recently felled is indicated by large masses of pitch and pitch tubes, mixed with reddish borings.

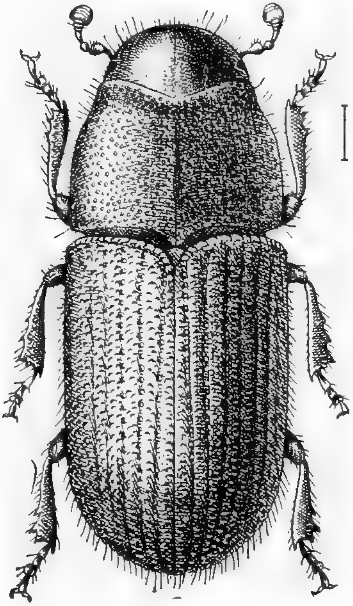

FIG. 95.—The black turpentine beetle (*Dendroctonus terebrans*): Adult. Greatly enlarged. (Author's illustration.)

SEASONAL HISTORY.

NORTHERN SECTION.

OVERWINTERING STAGES.

The winter is passed in and beneath the bark of trees and stumps attacked the preceding spring and summer, as parent adults, larvæ, and developed broods. The larvæ, as a rule, occupy the bark on the roots beneath the surface of the ground.

ACTIVITY OF OVERWINTERED BROODS.

The overwintered parent adults begin to extend their galleries or emerge and excavate new ones early in March or in April, depending on the locality, and probably continue active until June or later.

The overwintered broods of developed adults begin to emerge from the bark and fly early in March, at Tryon, N. C., or in April or May farther north and at high altitudes. Their principal work of excavating egg galleries is carried on during April and May, but is continued until hibernation begins in the fall.

The overwintered broods of large larvæ evidently complete their development and emerge in May and June, while some of the young larvæ may not complete their development and emerge until August or later. Therefore there is a succession of emerging adults throughout the greater part of the warm season, and it is not improbable that some of them pass the second winter as matured adults.

GENERATION.

The broods from eggs of overwintered parent adults evidently develop into adults, some of which emerge before hibernation begins in the fall, but it is probable that most of them pass the winter as matured adults. The overwintered broods of adults begin to deposit eggs in March and April, and continue to do so as successive broods appear until activity ceases in the fall. The eggs begin to hatch in March and April, the process continuing during April and May and until July or later. The principal active or feeding stage of the larvæ is during the period from May to July, but this stage may occur in any month of the year. The more advanced broods from eggs deposited in March evidently transform to pupæ and adults in July or August, but it appears that the principal period of transformation is in the fall, while the broods from eggs deposited in the summer do not transform until the following spring.

It is probable that some of the adults of the earlier broods may emerge in the fall, but no good evidence has been found that they do so in the northern section of the distribution. There is, however, such a complex overlapping of broods that it has been difficult to arrive at any conclusions regarding the normal period required for the development and emergence of all of the broods of a generation. It is evident, however, that in the northern section there is but one generation annually, and that in some cases it may require two years from the appearance of the earliest broods until all of the latest broods have developed and emerged and that, therefore, individuals of one generation may pass over two winters, first as young larvæ, and second as matured adults and larvæ, the latter from eggs deposited in the spring by the overwintered parent adults. It may also happen, as is known in some Curculionidæ, that some of the adults may live two years or more.

Southern Section.

In the region east of central North Carolina and south of western North Carolina and eastern Tennessee the seasonal history differs from that in the northern section, mainly in the fact that activity begins earlier in the spring and continues later in the fall, that in its more southern distribution it evidently continues active during the entire year, and that there is one complete generation and a partial second, if not two generations, annually, in the most southern localities.

HABITS.

This species prefers to enter the bark at the base of injured and dying trees and the stumps of those newly felled, though it will attack the main trunk of living trees, and if in sufficient numbers may cause their death without the aid of other agencies. Evidences of this have been noted by the writer on Long Island, N. Y., by Mr. W. F. Fiske in Texas, and by Dr. J. B. Smith (1899) in New Jersey. In the South, however, its principal injury is effected at the base of living pine trees, where its attack causes large scars, usually recognized as basal fire wounds.

It has been found in practically all of the pines within its range, and a few specimens were taken by Mr. Fiske excavating galleries in spruce in the high mountains of North Carolina.

A few specimens, taken by the writer in West Virginia from yellow and white pines, appear to represent quite a distinct variety of the normal southern form, while specimens of the normal form were taken from scrub and pitch pine at Kanawha Station, W. Va. The principal distribution of the species is south of the area occupied by the red turpentine beetle, but the two overlap along the middle Atlantic States from North Carolina to Long Island, New York, and along the mountains from North Carolina to Pennsylvania.

In its southern distribution it is often found in large numbers in the stumps of felled trees wherever winter and spring timber-cutting operations are carried on, and in lightning or fire-injured trees, but especially in the bark at the base of pine trees killed or injured by other insects. It shows a preference for the base of pine trees and stumps, but will breed in the bark on the underside of prostrate trunks.

The parent beetles excavate their broad, irregular, sometimes branched, longitudinal egg galleries for a distance of a few inches to many feet, through the inner, living bark. If the bark is living, healthy, and full of resin, the progress in making an entrance through the inner bark and extending the galleries is slow, so that often a large mass of resin, or so-called pitch, is ejected through the entrance burrow before the beetles overcome this obstacle. In the meantime the adults will often be found active, even when literally imbedded in the semiliquid mass of resin. The gallery is first extended upward above the entrance, though later it may be extended downward, or, if there is but little resin, downward from the start. Ten to forty, or more, eggs are placed in an elongated mass at intervals along one or both sides of the gallery. When the larvæ hatch they proceed in a body to feed on the bark and ultimately excavate a cavity, often many square feet in extent, which crosses and obliterates the primary gallery. When these large brood or larval chambers are excavated in the bark of a living tree, they are often found filled with liquid resin, yet the larvæ will continue their work, apparently undisturbed by it. The larvæ, which are stout, cylindrical, yellowish-white, footless grubs, with broad dorsal plates on the last abdominal segments armed with 6 stout spines, transform to pupæ and adults in separate or adjoining cells in the borings in the larval chamber, or in separate cells extended from the margin or into the roof of the chamber. When the broods of adults are fully developed and ready to emerge they usually bore through the intervening bark and congregate in the main chamber, where they mate and await the proper time for them to emerge. They then bore a few exit holes, or utilize the ventilating holes in the old gallery, through each of which many individuals emerge. In localities where this species is abundant it sometimes congregates in swarms of greater or less extent, accompanied by associates, guests, and enemies (see pp. 159–160).

ECONOMIC FEATURES.

In general, this species is of secondary importance in its relation to the death of pine timber, but occasionally it has been found in the rôle of the primary and only cause of the death of trees, especially on Long Island, New York, and in New Jersey. The principal injury, however, is usually confined to the base of living pine trees. The broad larval chambers separating the bark over areas of greater or less extent might in many cases heal without serious harm, but the dead bark, with the pitch masses on the outside and the dried resin and borings beneath, offers the most favorable conditions for subsequent injuries by forest fires, and thus these larval chambers are the primary cause of a very large percentage of the so-called "fire scars" or fire wounds which are so prevalent at the base and lower portion of the trunks of living trees in the South. If a forest fire burns the bark and resin and exposes the wood, it becomes dry and is usually mined by round-headed and flatheaded wood-borers. Or the wood may become either pitchy or decayed, so that the next fire burns deeply into it and kills a larger area of the bark. Thus each subsequent fire contributes to an extension of the wound until in many cases the tree is so weakened that it is broken down by wind or attacked and killed by other barkbeetles. In the aggregate, this primary injury by the beetle results in very extensive losses of some of the best timber.

EVIDENCES OF ATTACK.

The first evidences of the work of the beetle are found in fresh masses of pitch, or large pitch tubes, mixed with reddish borings, at or near the base of living trees and the stumps of recently felled ones. Subsequent evidence, until destroyed by fire, is found in the old pitch masses on the surface, traces of primary galleries under the bark or on the wood, or round holes in the loose dead bark over the wound.

The commercial value of the trees attacked by this beetle is not materially affected until after the injury has been extended into the trunk by fire, wood-boring insects, decay, etc., to a point where the vitality is greatly reduced or the tree becomes worthless.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication of this beetle and its injury to living timber are found in sections where for several years a large amount of pine timber has been killed or injured by insects, or felled and broken by storms, lumbering operations, etc., followed by a year in which no timber dies or is injured or killed. Under these conditions the vast numbers of this insect which have bred in the injured and dying trees will, through necessity, attack the living trees and cause serious and widespread damage the first year. This will usually be followed by little or no damage in succeeding years, unless favorable conditions are again presented for their multiplication. The first year after the disappearance of the southern pine beetle in West Virginia the swarms of the red turpentine beetle caused extensive injuries to the base of living trees, but for many years thereafter the species was rare and did no harm. Unfavorable conditions for injury to living trees by this insect are found in healthy forests under a system of forest management which requires more or less continuous timber-cutting operations to utilize the older matured, injured, and dying trees.

METHODS OF CONTROL.

Since the habits of this beetle and the character of the injury caused by it are in marked contrast to those of nearly all other species of the genus, the problem of control is quite different. The principal injury is to the base of living trees, which, in itself, may be slight, but when aggravated and extended by subsequent and quite different causes may become quite extensive. Therefore the object should be to prevent the primary injury by preventing the undue multiplication of the beetle, or by furnishing a continuous supply of more attractive breeding places, as in the case of continued lumbering operations. The first may be accomplished if within quite an extensive area the infested bark is removed from the base of insect-killed, lightning-struck, and otherwise injured or dying trees, as well as from the stumps of those felled during local or sporadic timber-cutting operations. This work should be done during the fall and winter following infestation, beginning with the first of September and ending with the first of March. Where only a few trees in a lawn or park are involved, or even where many are attacked in a forest under a complete system of forest management, serious injury may be prevented by cutting the beetles out of the bark with a chisel or knife as soon as the discharge of resin on the bark indicates their presence; or they can often be killed quickly and effectually by means of a stout wire inserted into the entrance burrow, if done before the parent beetles have extended their galleries into the inner bark beyond 2 or 3 inches.

It appears that in places where continued timber-cutting operations are carried on there are sufficient and most attractive breeding places for this beetle; therefore in such sections little or no damage to the living and otherwise uninjured trees will result. If the cutting should be discontinued for one or more years throughout a large area, and if it seems desirable, the infested bark may be removed from the majority of the stumps of trees felled during the fall, winter, and spring, or the brush piled around the stumps and burned, the work to be done during the fall and winter following the cutting.

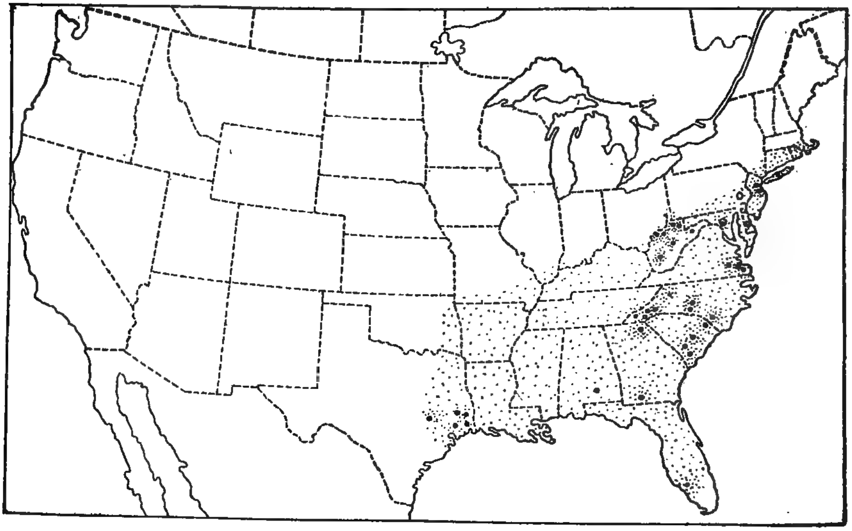

FIG. 96.—The black turpentine beetle: Distribution map. (Author's illustration.)

In case the removal of the bark from the stumps is required in timber-cutting contracts, it should be specified that the bark must not be removed until after it becomes infested with broods of larvæ, or, in other words, the stumps of trees felled in the fall, winter, and spring should not be barked to destroy the broods of this beetle before the following June or July, but the barking must be completed before the following March. Trees felled during the spring and summer to serve as traps should not have the bark removed for at least two months after such operation.

In some sections of the country this beetle appears to be attracted to the trunks of felled trees much more than in others, depending probably on the species of tree and local conditions relating especially to the presence or absence of certain other insects which would or would not interfere with the development of their broods.

BASIS OF INFORMATION.

Information in regard to this beetle is based on investigations by the writer in West Virginia, at Romney, July, 1891; at Dellslow, March and November, 1891; at Crow, April, 1893; in Randolph County, in spruce forest, May, 1893; at Kanawha Station, July, 1903; in North Carolina, at Fletchers, July and November, 1902; at Tryon, July, 1902, March, 1903, and October, 1903; at Boardman, November, 1904; at Lumber, S. C., March, 1903; at Kirbyville, Tex., November, 1902; on Long Island, New York, September, 1903; at Roosevelt, W. Va., and Virginia Beach, Va., June, November, and December, 1907; on investigations by Mr. W. F. Fiske in North Carolina, at Tryon, March, April, May, and November, 1903, November, 1904, and March, May, and July, 1905; at Pisgah Ridge Mountain, September, 1904; at Pink Beds, September, 1904, and May, 1905; at Biltmore, May, 1905; at Cornelia, Ga., November, 1903; at Thomasville, Ga., March, 1905; at New Landing, S. C., August, 1903; at Chicora, S. C., November, 1904; at Call, Tex., February, 1905, and at Deweyville, Tex., March, 1905. Additional localities through correspondence and from other collections are: New Brunswick and Lakewood, N. J.; Islip, Long Island, New York; Calhoun, Ala.; Tarkington and Austin, Tex.; Tampa, Fla., and Marion County, Fla.; Glen Allen and Fort Monroe, Va. Represented in the forest-insect collection of this Bureau by over 400 specimens, including all stages and work.

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(Refers to *D. terebrans* proper and not to *D. valens* Lec., which was often confused with it.)

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No. 23. THE RED TURPENTINE BEETLE.

(*Dendroctonus valens* Lec.[a] Figs. 97–102.)

The red turpentine beetle is a large, stout, light to dark red, cylindrical barkbeetle, 5.7 to 9 mm. in length, with head broad, convex, lacking grooves or longitudinal impressions; the pronotum broad, coarsely punctured, becoming finer toward base, the sides slightly narrowed toward the head, but not strongly constricted; the elytra with coarse, transverse to oblique rugosities between distinct to obscure rows of punctures; the declivity convex, with moderately deep grooves, and the intervening spaces slightly convex and roughened; the entire body sparsely clothed with long hairs. (See fig. 97.)

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[a] Referred to under *Dendroctonus terebrans* in earlier literature.

It attacks the living bark on injured, dying, healthy, and felled pine and spruce in eastern United States and Canada, north from the mountains of North Carolina, westward to the Pacific coast, and southward from British Columbia into Mexico. The parent beetles excavate broad, somewhat irregular, winding, longitudinal egg galleries (fig. 98) through the inner bark and groove the surface of the wood. The eggs are placed in groups or masses at intervals along the sides of the galleries. The stout, yellowish-white, cylindrical larvæ, with reddish heads and stout spines on the dorsal plates of the last abdominal segments, do not make separate larval mines, but all feed together and eat out cavities in the inner bark from a few inches square to several feet square (see fig. 98). They transform to pupæ and adults in separate or closely joined cells in the inner bark, or inner portion of the outer bark, or in mines extending from the social chamber. The broods work independently of other species and occupy and separate the bark around the base of trees and stumps (see fig. 99), often extending their work for a foot or more onto the roots beneath the surface, and the broad larval chambers are often filled with semiliquid resin, without injury to the occupants. The

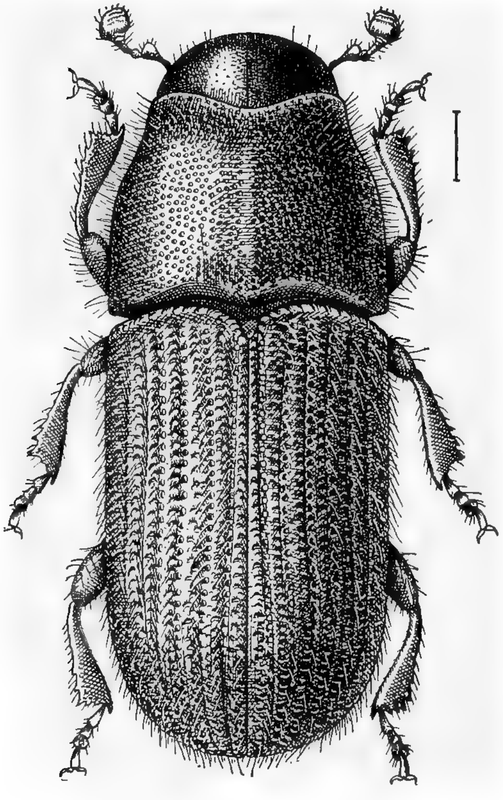

FIG. 97.—The red turpentine beetle (*Dendroctonus valens*): Adult. Greatly enlarged. (Author's illustration.) (See also fig. 4, larva; fig. 5, pupa.)

attack on living trees and on the stumps of those recently felled is indicated by large masses of pitch and pitch tubes, mixed with reddish borings.

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed in and beneath the bark of trees and stumps attacked the preceding spring and summer, as parent adults, larvæ, and developed broods, the larvæ, as a rule, occupying the bark on the roots beneath the surface of the ground.

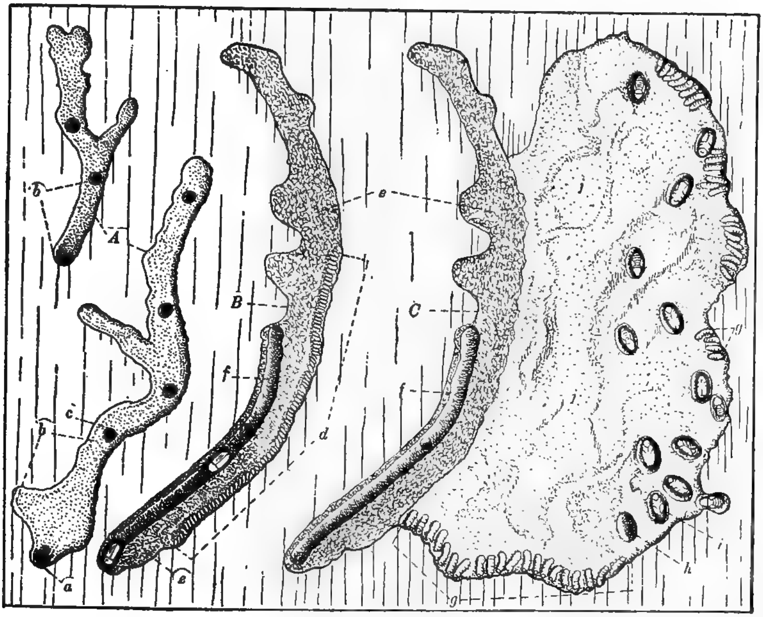

FIG. 98.—The red turpentine beetle. Egg galleries and larval chamber: *A*, Incomplete egg galleries with boring dust removed; *B*, normal gallery; *C*, advanced stage of work; *a*, entrance burrow; *b*, basal section; *c*, ventilating burrow; *d*, egg nest with eggs; *e*, boring dust; *f*, subsequent or inner galleries; *g*, larvæ at work; *h*, pupal cell in boring dust mixed with resin. (Author's illustration.)

ACTIVITY OF OVERWINTERED BROODS.

The overwintered parent adults begin to extend their galleries during the first warm weather in March, April, or June, depending on locality, and probably continue to work in these, or excavate new galleries, until July and August, or later. It is probable that after finishing one gallery they emerge and excavate new ones, and that this process may be repeated during the summer and fall. It is also not improbable that some of them may pass the second winter. The overwintered broods of young adults begin to emerge from the bark in April and continue to do so during May and June, and less commonly until August, or later; they excavate galleries principally in

May and June, and continue activity until hibernation begins in the fall. The overwintered broods of large larvæ evidently complete their development to pupæ and adults and emerge by July, while the young larvæ may not complete their development and emerge until in September and October, and some individuals may pass the second winter as adults.

GENERATION.

The overwintered broods of adults evidently begin to excavate galleries and deposit eggs in the period from April to June, depending on latitudes and altitudes, and continue their activity as successive broods emerge, during June, July, August, and until September, or later. The eggs begin to hatch probably within a week or ten days after they are deposited. This process continues during May and June or July, until September, or later. The larval development is principally during July, August, and September, but continues until hibernation begins. The more advanced larvæ begin to transform to pupæ and adults in August, while some of the others continue transformation during September and October, until cold weather, when larvæ of all stages, pupæ, and adults are found.

While it is possible that some of the more advanced broods in the warmer localities may emerge in the late summer or early fall, it is evident that by far the greater number pass the winter in the bark, where they develop and emerge in the following spring and summer.

The possibility of individuals of the overwintered parent adults, as well as of young adults of the overwintered brood, excavating more than one gallery, during the season, together with the probability that some individuals of a single generation may pass through two or even three winters, involves such an overlapping of broods of different generations that even with extensive observations it has been impossible to arrive at any definite conclusions regarding the normal period required for the development and emergence of all of the broods of a generation.

HABITS.

This species prefers to enter the bark of injured or dying trees or that of the stumps and logs of those which have been felled, but often attacks the perfectly healthy bark on the base and roots of healthy, living trees.

It has been found in practically all of the eastern pines and spruces within its range of distribution, and in nearly all of the principal western pines, but in none of the western spruces except the white spruce in the Black Hills of South Dakota. It is probable that none of the species of pine and spruce growing within its range is exempt from its attack. We have no records of it in fir (Abies), or in Douglas fir, and it is not likely that it will infest these trees, but it has been found in the eastern larch.

It is often exceedingly abundant in the stumps of felled trees where timber-cutting operations are carried on, in fire-scorched trees, and especially in the bark at the base of those killed by other species of Dendroctonus, or by lightning, or storm, or otherwise injured and broken. It shows a decided preference for the bark on the base of pine trees and stumps, and is rarely common in the logs or prostrate trunks, even of pine.

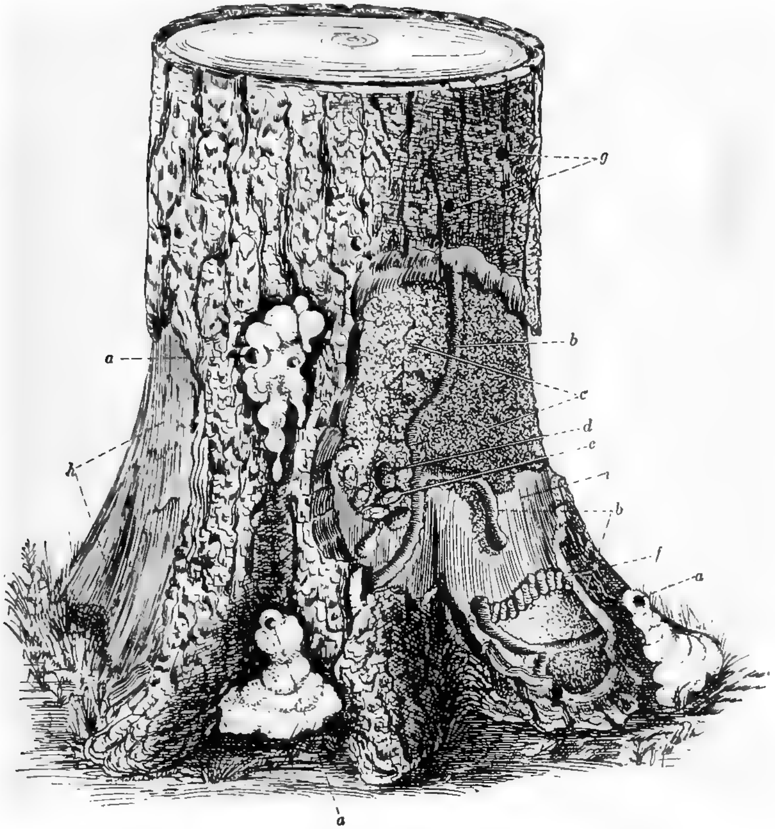

Fig. 99.—The red turpentine beetle. Work in bark at base of tree: *a*, Entrance and pitch tube; *b*, egg gallery; *c*, boring dust and resin; *d*, pupal cell; *e*, pupa; *f*, larvæ at work feeding on inner living bark; *g*, exit burrows; *h*, resulting old scar or basal wound, often referred to as basal fire wound; *i*, inner bark with outer corky bark removed. (Author's illustration.)

The parent beetles excavate their broad, irregular, sometimes branched, longitudinal egg galleries, from a few inches to many feet in length, through the inner living bark. If the bark is living and healthy and full of resin, the progress in making an entrance through the inner bark and extending the galleries is slow, and often large masses of resin or so-called pitch are pushed out at the entrance before they overcome this obstacle. In the meantime the adults will often be found active, even when literally embedded in the semiliquid mass of resin. The gallery is first extended in one direction above the entrance, but later it may be extended below, or, if there is but little resin, may extend downward from the start. Ten to forty or more eggs are placed in an elongated mass along one or both sides of the gallery, and when the larvæ hatch they proceed in a body to feed on the bark and ultimately excavate a cavity, often many square feet in extent (fig. 101), which crosses and obliterates the primary gallery. When these large social brood or larval chambers are excavated in the bark of a living tree, they are often found filled with liquid resin, yet the larvæ will continue their work, apparently undisturbed by it. The larvæ, which are stout, cylindrical, yellowish-white, footless grubs, with broad dorsal plates on the last abdominal segments armed with six stout spines, transform to pupæ and adults in separate or adjoining cells in the borings in the larval chamber or in separate cells extended from the margin or into the roof of the chamber. When the broods of adults are fully developed and ready to emerge, they usually bore through the intervening bark and congregate in the main chamber, where they mate and await the proper time for them to

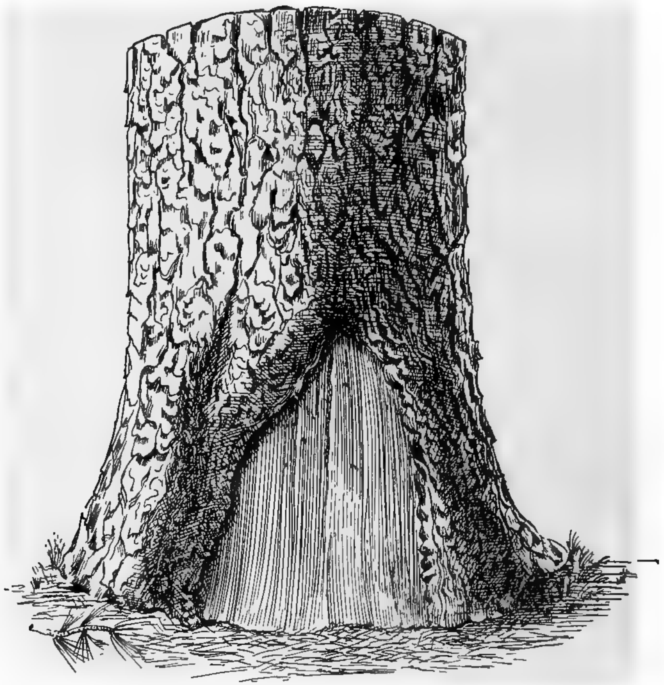

FIG. 100.—The red turpentine beetle: Basal wound in living tree resulting from primary injury by this species. Often mistaken for fire wound. (Author's illustration.)

emerge. They then bore a few exit holes or utilize the ventilating holes in the old gallery, through each of which many individuals emerge. In localities where this barkbeetle is abundant it sometimes congregates in swarms of greater or less extent, accompanied by associates, guests, and enemies.

The flight habits of all of the species of Dendroctonus are more or less obscure, but some observations have been made on the swarming habits of this species, as recorded by the writer in Bulletin No. 56 of the West Virginia Agricultural Experiment Station, pages 346–348, which are perhaps worthy of repetition in this connection:

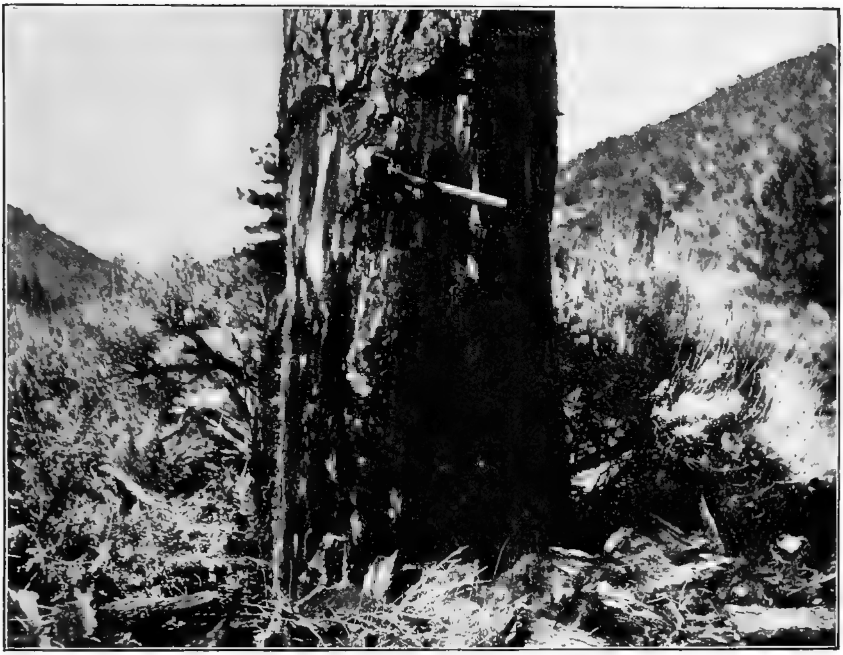

FIG. 101.—Western yellow pine showing work of the red turpentine beetle, Flagstaff, Ariz. (Original.)

Returning to Morgantown, W. Va., on May 12, I learned from my assistant, Mr. W. E. Rumsey, and others, that a great swarm of barkbeetles had passed through Morgantown on May 4. They were especially abundant in and around furniture factories and new houses that were being painted, and wherever there was an odor of turpentine. In fact, they came, as it was expressed, "like a hailstorm," into open windows and doors, and were the cause of considerable alarm on the part of the inhabitants, who thought that a plague of bugs had visited the place. The new greenhouses that were being constructed and painted at the experiment station were central points of attraction. Here they occurred like swarms of bees.

While this remarkable swarm consisted mainly of the turpentine barkbeetles, it would appear from the dead and living examples that I found in the greenhouses and adhering to the paint that it was accompanied by numerous species of bark and timber beetles and also by some of their enemies. I was greatly disappointed that

I did not see this swarm or the many others like it which I subsequently learned occurred in different sections of the State about the same time, since it would have been very interesting and important to know the number of species that occurred in them and the approximate proportions of each.[a]

On my way to the spruce forests on May 20, I was informed at Bretz, Tucker County, W. Va., that the swarm had occurred there on April 30. They came from the southeast and "showered against the windows like hail," and entered through the open doors into the houses in such numbers that they had to be swept out. I found a few examples of the turpentine beetle in the office of Mr. Shaw, who informed me that it was the same insect that occurred in the swarm. At Mr. Frank Bennet's, about 15 miles farther up the river (Dry Fork of Cheat), I learned that a similar swarm had visited that section about the same time as the one at Bretz. Here I found large numbers of the turpentine beetle in the webs of the apple tree tent caterpillar. The swarm that passed through Bretz and Morgantown doubtless originated in the dead pine timber of Hampshire, Hardy, and Pendleton counties, and taking a northwesterly course passed over the Allegheny Mountains and through the great spruce forests of Randolph and Tucker counties about April 30, and reached Morgantown on May 4. The swarm was also reported from different points along the West Virginia and Pittsburg Railroad and from Pocahontas and Greenbrier counties, which would indicate that this remarkable occurrence was quite general throughout the spruce and pine areas. The fact that the turpentine beetle had been found so common attacking living trees and occurred in such enormous numbers in these swarms, together with the fact that numerous other species occurred in the swarms and in the bark of dying trees, led one very naturally to the conclusion that even if the destructive species had become extinct the timber would continue to be killed by these surviving barkbeetles.

The vast numbers of the red turpentine beetle which had bred in the trees killed by the southern pine beetle during 1891 and 1892, finding no more trees dying from this cause in 1893, attacked the base of living pine and spruce, and did considerable damage during the summer of 1893, but there was little or no damage caused by it in 1894, and for many years thereafter it was a rare insect in the coniferous forests of West Virginia examined by the writer.

ECONOMIC FEATURES.

In general, this species is of secondary importance in its economic relations to American forests. In the East it has never been found as the primary and only cause of the death of trees; in California, both at Monterey and in the Sierra Nevada Mountains, it is more aggressive, and it appears that numbers of trees have been killed or seriously damaged by it. The principal injury is to the base of living pine and spruce, especially the former. While it sometimes infests the bark 8 or 10 feet above the base and in sufficient numbers to kill a few trees, it is an abnormal habit and result. It sometimes completely separates the bark around the base, but the wounds are so completely covered by resin that a tree so affected rarely dies from this injury alone, but often from secondary injury by fire or other insects. The broad larval chambers separating the bark over areas of greater or less extent might in many cases heal without serious harm, but the dead bark with the pitch masses on the outside and the dried resin and borings beneath offer the most favorable conditions for subsequent injuries by forest fires, and thus are the primary cause of a very large percentage of the so-called "fire scars" or fire wounds (fig. 100) which are so prevalent at the base and lower portion of the trunks of living trees in the dry pine areas of the western mountains. One or more years after the injury by the beetle, a forest fire may burn the bark and resin and expose the wood, which becomes dry and is then bored by round-headed and flat-headed wood-borers, or it becomes pitchy or decayed, so that the next fire burns deep into the wood and kills a larger area of the bark. Thus each subsequent fire contributes to an extension of the wound until in many cases the tree is so weakened that it is broken down by wind or attacked and killed by other barkbeetles. In the aggregate, this primary injury by the beetle results in very extensive losses of some of the best timber.

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[a] The species found in the greenhouses and on paint which evidently came in the swarm, May 4, 1893, are as follows:

1. *Monarthrum mali* Fitch.
2. *Gnathotrichus materiarius* Fitch.
3. *Xyleborus xylographus* Say.
4. *Tomicus cacographus* Lec.
5. *Hylastes cavernosus* Zimm.
6. *Hylastes gracilis* Lec.
7. *Hylurgops glabratus* Zett.
8. *Dendroctonus terebrans* Oliv.[=*valens* Lec., which greatly predominated in the swarm.]
9. *Ips fasciatus* Oliv.

EVIDENCES OF ATTACK.

The first evidence of the work of the beetle is found in the fresh masses of pitch or large pitch tubes, mixed with reddish borings, at or near the base of living trees and stumps of recently felled ones. Subsequent evidence, until destroyed by fire, is found in the old pitch masses on the surface or traces of primary galleries under the bark or on the wood, and round holes in the loose, dead bark over the wound.

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

The commercial value of the trees injured by this beetle is not materially affected until after the injury has been extended into the trunk by fire, wood-boring insects, decay, etc., to a point where the vitality is greatly reduced or the tree becomes worthless.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication of this beetle and for its injury to living timber are found in sections where for several years a large amount of pine timber has been killed or injured by insects, or felled and broken by storms, lumbering operations, etc., followed by a year in which no timber dies or is injured or killed. Under these conditions the vast numbers of this insect which have bred in the injured and dying trees will, through necessity, attack the living trees and cause serious and widespread damage the first year. This will usually be followed by little or no damage in succeeding years, unless more favorable conditions are again presented for their multiplication.

Unfavorable conditions for injury to living trees by this insect are found in healthy forests under a system of forest management which requires more or less continuous timber-cutting operations to utilize the older matured, injured, and dying trees.

METHODS OF CONTROL.

Owing to the peculiar habits of this beetle and the character of the injury caused by it, contrasting strongly with those of other species of the genus except the black turpentine beetle, the problem of control is quite different from that relating to nearly all of the other species. The principal injury is to the base of living trees, which, in itself, may be slight, but when aggravated and extended by subsequent and quite different causes may become quite extensive. Therefore the object should be to prevent the primary injury, by preventing the undue multiplication of the beetle or by providing more attractive and continued breeding places. The first may be accomplished within quite an extensive area if the infested bark is removed from the base of insect-killed, lightning-struck, and otherwise injured or dying trees, as well as from the stumps of local or sporadic timber-cutting operaations, the work to be done during the fall and winter following infestation, beginning with the first of September and ending with the first of March. When only a few trees in a lawn or park are involved, or even where many are attacked in a forest under a complete system of forest management, serious injury may be prevented by cutting the beetles out of the bark with a chisel or knife, as soon as the discharge of resin on the bark indicates their presence. Often they can be killed quickly and effectually by means of a stout wire inserted into the entrance burrow, if done before the parent beetles have extended their galleries in the inner bark beyond 2 or 3 inches.

It appears that continued timber-cutting operations offer sufficient and more attractive breeding places for this beetle. Therefore, in sections where these are carried on little or no damage to the living and otherwise uninjured trees will result; but if the cutting should be discontinued for one or more years throughout a large area the infested bark should be removed from the majority of the stumps of trees felled during the fall, winter, and spring, the work to be done during the fall and winter following the cutting.

In case the removal of the bark from the stumps is required in timber-cutting contracts, it should be specified that the bark must not be removed until after it becomes infested with broods of larvæ, or, in other words, the stumps of trees felled in the fall and winter should not be barked to destroy the broods of this beetle before June or July, but the barking must be completed before the following March. Trees felled during the spring and summer to serve as traps should not have the bark removed for at least two months after the trees are felled.

In some sections of the country this beetle appears to be attracted to the trunks of felled trees much more than to those of others, depending probably more on the species of tree and local conditions relating especially to the presence or absence of certain other insects which would or would not interfere with the development of their broods.

In the vicinity of Monterey, Cal., it was found by the writer abundant in September in the bark of trees felled by storm the previous April. This suggested the utilizing of trap trees in such localities to attract the beetles to the bark of the trunks, as well as to that on the stumps.

BASIS OF INFORMATION.

The above statements are based on investigations by the writer in many localities in different sections of West Virginia in 1890 to 1894; at McCloud and Berkeley, Cal., Grants Pass and Albany, Oreg., near Spokane, Wash., and at Moscow, Idaho, April to June, 1899; in the Black Hills, South Dakota, 1901 and 1902; at Priest Lake, Idaho, August, 1902; at Del Monte and Monterey, Cal., September, 1902; at Williams, Ariz., September, 1902; at Vermejo, N. Mex., May, 1903; at Flagstaff, Ariz., May, 1904; in the Yosemite National Park, California, June, 1904; at Brunswick and Portland, Me., May and June, 1900; at Malden, Wyoming [Melrose], and Lynn Woods, Mass., May, 1906 (in Norway spruce defoliated by gipsy moth); at Milford, Pa., May, 1905; at Pink Beds, N. C., July, 1904; at Manitou Park and Palmer Lake, Colo., October, 1905; in Ventura County, Cal., June, 1904; at Garland, Colo., June, 1906; on Grand Island, Michigan, July, 1907; by Mr. W. F. Fiske, at Webster, N. H., June, 1904; at Pink Beds, N. C., May, 1905; on Grand Island, Michigan, October, 1906; at Capitan and Cloudcroft, N. Mex., March to May, 1907; by Mr. J. L. Webb, in the Black Hills, South Dakota, June to October, 1902; at Flagstaff, Ariz., June to August, 1904; in the vicinity of Centerville, Idaho, May to August, 1905; in the Capitan Mountains, Lincoln National Forest, and White Mountains, New Mexico, and in the Chiricahua National Forest, Arizona, June to September, 1907; by Mr. H. E. Burke, at Palo Alto, Cal., May, 1905, May, 1906, and September, 1906; in the Yosemite National Park and vicinity, at Wawona, Summerdale, Little Yosemite, and Yosemite, Cal., May to September, 1906; at Kamas, Panguitch, and Panguitch

Lake, Utah, Joseph, Oreg., and Palo Alto and Pacific Grove, Cal., June to October, 1907. Additional localities through correspondence and from other collections are: Missoula and Ovondo, Mont.; Fredonia, Paradise, Williams, Flagstaff, and Tucson, Ariz.; Franconia and Pike, N. H.; Orono and Limerick, Me.; Glen Allen, Va.; Le Moin, Visalia, Ventura County, Sisson, Placer County, Siskiyou County, and Dunsmuir, Cal.; Kansas; Helena, Mont.; Coldridge, N. Mex.; Powder River, Custer County, Colo.; Skykomish River, Washington; Hood River,

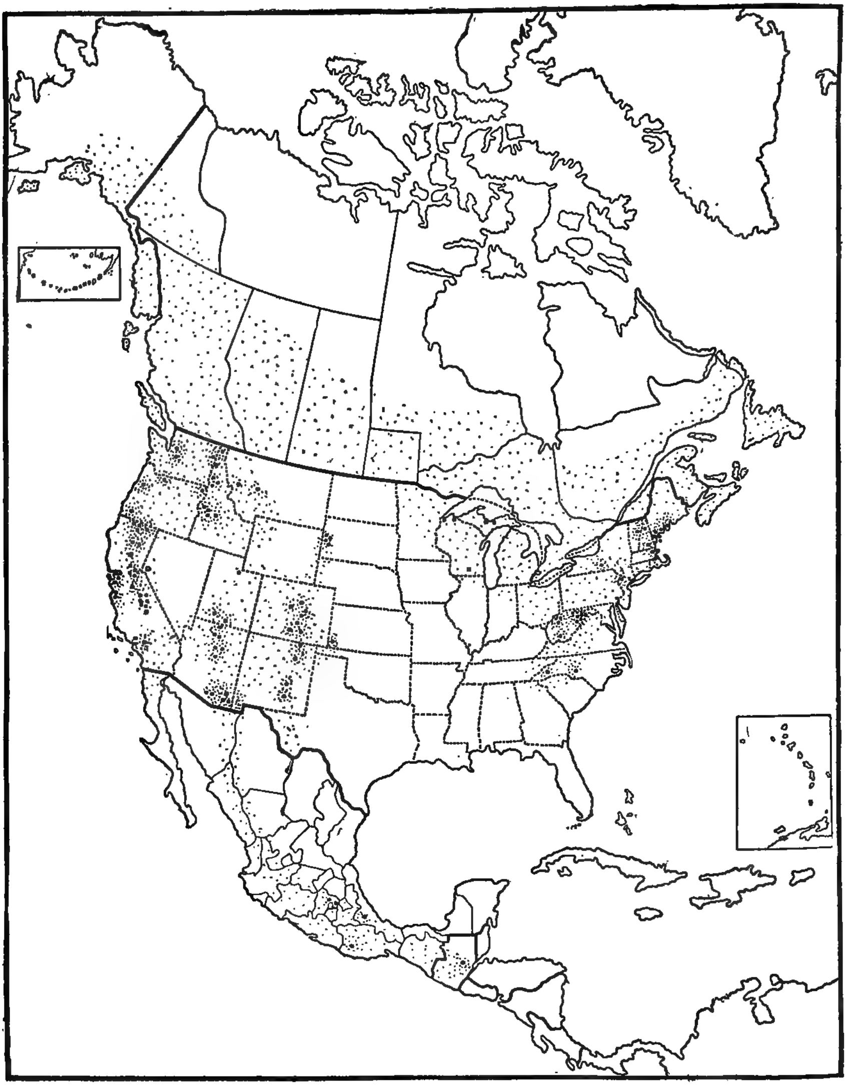

FIG. 102.—The red turpentine beetle: Distribution map. (Author's illustration.)

Oreg.; Coeur d'Alene, Idaho; Duluth, Minn.; Marquette, Mich.; Cambridge, Mass.; Chalco, Chihuahua, Mexico City, Michoacan, Ponada, and Satazin, Mexico. It is represented in the forest-insect collections of the West Virginia Agricultural Experiment Station and of the Bureau of Entomology by more than 5,000 specimens.

While specimens from all over the country are included under one name, it is believed by the writer that there are a number of more or less distinct so-called races and varieties, and possibly some forms are specifically distinct, but, owing to the great variation in all determined characters which can be used for such a separation, it is thought best to leave all of them under one name. The species is easily separated from the southern turpentine beetle by its light to dark red color, except when compared with the immature reddish specimens, and then the coarser punctures on the prothorax and coarser teeth of the tibia of the latter will serve to indicate the difference.

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O

NEW JERSEY
AGRICULTURAL EXPERIMENT STATIONS

THE PERIODICAL CICADA

A Circular of Warning.

Brood II. of the periodical *Cicada*, or, as it is better known, the "17-year Locust," appeared in New Jersey in 1894, and is due to appear again in 1911. According to the records gathered in 1894, the brood covers practically all of Bergen county, scattered areas in Passaic county, small areas near Huntsburg and Papakating in Sussex county, practically all of Morris, Union, Essex and Hudson counties, a few areas in Mercer county, irregular areas all over Middlesex county, scattering points in the eastern part of Monmouth county, small patches in Ocean and Burlington counties, Pensauken and vicinity in Camden county, scattering sections at the southwestern part of Gloucester and Salem counties, irregular areas throughout Atlantic and Cumberland counties, and all the wooded sections on the Cape May Peninsula. There is, therefore, no county entirely free from the insects; but they do not approach the Delaware river closely except in Camden county, and, in a general way, may be said to be most abundant in the eastern half of the State.

The insects will appear during the last days of May, 1911, and will continue throughout June; disappearing by the end of the month. The injury is done by the females in laying the eggs in twigs and small branches, making slits that do not heal. These result in the ultimate death beyond the point of injury of every punctured branch less than one-half an inch in diameter, and, where there are many punctures on the trunks of small trees or on branches up to three-quarter inch, these are apt to be seriously injured or killed.

Farmers, fruit-growers and others who contemplate setting out trees or shrubs during the fall of 1910, or spring of 1911, in the infested areas, are warned of the danger of injury from these *Cicadas*. If trees or shrubs must be set, put out either very small trees and cut back severely, so as not to offer attractions to the insects, or set large trees with many branches and cut back no more than absolutely necessary until after July 1st, so as to offer the insects a chance to oviposit in wood that can be spared. Burn all the cut infested wood.

In established, young orchards or other plantations, do not prune more than necessary, so as to distribute any injury that may be caused. On large trees no appreciable injury will be noted, but there may be a serious cutting of the crops borne on small shoots and branches. There is no way of poisoning the insects for they do practically no feeding, and it is not in the least dangerous to handle them. All insectivorous birds feed freely on these *Cicadas*, and so does the ordinary farm poultry of all kinds. Sparrows take a malicious delight in tearing them to pieces, and little damage need be expected where these birds occur in large numbers.

The undersigned will be grateful for all information as to the places where the insects appear.

JOHN B. SMITH,
Entomologist.

New Brunswick, August 1st, 1910.

University of Maine.

Maine Agricultural Experiment Station

ORONO

BULLETIN No. 173. DECEMBER, 1909.

CHERMES OF MAINE CONIFERS.

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BULLETIN No. 173.

CHERMES OF MAINE CONIFERS*

By Edith M. Patch.

The Pine Leaf Chermes.

Chermes pinifoliae Fitch.
Chermes abieticolens Thos.

It is manifestly a pleasure to reinstate a species lost in a list of synonyms and an unusually interesting situation is found in the present study which justifies removing a species merged by error with two widely different Chermes† one on pine and one on spruce, and uniting these two forms in turn under the name of the form first described.

The species under consideration develops in a cone-like gall on the black spruce and migrates to the needles of the white pine to oviposite and was named, as commonly happens with aphids with two distinct host plants, separately in each situation.

The evidence concerning each will be taken in turn. Fitch's description of *Chermes pinifoliae*,‡ (though without figures or much structural detail) is excellent in that it selects several distinctly characteristic phases of this species and is sufficient to distinguish it from any of the other *Chermes* recorded in this paper.

Fitch's published account of the species is here given in full:

"267. Pine-Leaf Chermes, *Chermes Pinifoliae*, new species.

"Stationary upon the leaves, usually towards their ends, puncturing them and sucking their juices, a very small black fly 0.08** long to the tip of its abdomen, and 0.12 to the end of its wings, which are dusky gray, its abdomen dusky red and slightly covered with fine cottony down.

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* Papers from the Maine Agricultural Experiment Station: Entomology No. 39.

† *Chermes pinicorticis* and *Chermes abietis*.

‡ Trans. N. Y. Agric. Soc. 17: 741; id. Rept. Ins. N. Y. 4: 55, 1858.

** Fitch's measurements are given in decimals of inches.

"The females of these insects do not extrude their eggs. Clinging closely to the leaf with their heads towards its base, they die, their distended abdomens appearing like a little bag filled with eggs. The outer skin of the abdomen soon perishes and disappears, leaving the mass of eggs adhering to the side of the leaf, but completely covered over and protected by the closed wings of the dead fly. I have met with the dead females thus adhering to the leaves the first of July, and have noticed the same insects on the leaves in full life and vigor the middle of May.

"The rib vein of the fore wings runs straight to the outer margin forward of the tip, and gives off from its middle on the outer side a very oblique branch which runs to the outer margin, its tip producing a slight angular projection to the edge of the wing, and the whole space on the outer side of the rib vein beyond this branch is more opake than the rest of the wing and of a smoky yellowish color. From its inner side the rib vein sends off three simple oblique veins, the last one of which ends in the extreme tip of the wing. The hind wings have an angular point on their outer side beyond the middle, and a longitudinal rib vein, which, forward of its middle sends off a branch almost transversely inward, its tip curved backward. The antennae are short, thread-like, and composed of four or five small joints. It will hence be seen that this insect is a true Chermes—the first species of this genus that has been discovered in this country."

The fact that a *Chermes* described by Fitch as 0.08 inches long to the end of the abdomen (0.12 inches long to the tip of the wings) and the accurate and characteristic account of the place and manner of ovipositing on the pine needles could have been considered the same as *Chermes pinicorticis** for the past 40 years, is sufficient proof that none of the observers who have worked with *pinicorticis* have been familiar with Fitch's other species, i. e., *pinifoliae*.

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* 1869, Shimer. Trans. Am. Ent. Soc. II, 383.
1884, Osborn. Bull. A. E. S. Ia. No. 2, 97-105.
1898, Storment, Rept. Ent. Ill. 20 iii-xxiii, pl. i-ii.

Thomas in his third report makes the following statement† concerning *abieticolens*.

"CHERMES (ABIETICOLENS?)

"Adeleges of the Spruce. Packard.

"A rather large species mentioned by Dr. Packard as 'found in abundance on the spruce in Maine, where it produces swellings at the ends of the twigs, resembling in size and form the cones of the same tree.' The specific name is applied provisionally and only for use in this report. This is certainly distinct from the European species *Chermes abietis* Linn., which is much smaller, of a bright reddish-brown color, with the wings tinged with green."

Packard‡ reports this species as follows:

"37. The Spruce Bud-louse, *Adelges abieticolens*, Thomas.

"Deforming the terminal shoots of the spruce, producing large swellings, which would be readily mistaken for the cones of the same tree.

"We take the following account and illustration from our Guide to the Study of Insects:

" 'The genus *Adelges* was proposed by Vallot for certain broad, flattened plant-lice which attack coniferous trees, often raising swellings on twigs like pine and spruce cones. The antennae are short, 5-jointed and slender; there are three straight veinlets arising from the main subcostal vein and directed outwards, and there are no honey tubes; otherwise these insects closely resemble the Aphides. A species closely related to the European *Adelges* (*Chermes*) *coccineus* of Ratzeburg, and the *A. strobilobius* of Kaltenbach, which have similar habits, we have found in abundance on the spruce in Maine, where it produces swellings at the ends of the twigs resembling in size and form the cones of the same tree. We would add that each leaf-bud is enlarged, having an *Adelges* under it. As those nearest the base mature first and leave their domicile, the deformed leaf-bud stands out from the axis of the shoot, thus giving the conelike appearance to the end of the shoot.'

"This has since been described by Prof. Cyrus Thomas in his Third Report on the Injurious Insects of Illinois, p. 156."

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† Rept. Ent. Ill. 8: 156, 1879.

‡ Insects Injurious to Forest and Shade Trees.

That Packard himself was familiar with the galls of both *abieticolens* and the European *abietis* and considered them distinct is shown by his item which follows the foregoing one just quoted:

"38. The European Spruce Bud-louse, *Adelges abietis* Linn.

"We observed this species in considerable numbers on the Norway spruces on the grounds of the Peabody Academy of Science at Salem, in August, 1881. The deformation produced in the terminal buds and twigs were like those figured in Ratzeburg's Die Waldverderbniss, Bd. i, Pl. 28, figs. 1, 2."

Thomas states that he was certain that he was dealing with a distinct species, and one brief item is sufficient to prove him correct, for he uses one difference which is alone enough to separate these two species when he says that with the European species, *Chermes abietis* Linn. "the wings are tinged with green". While color distinctions are often an unsafe basis, it is steadfast one here, for *Chermes abietis* has uniformly and conspicuously green wings while the dark species developing in that Spruce gall ("found in abundance on the spruce in Maine") which when deserted "stands out from the axis of the shoot, thus giving the cone-like appearance to the end of the shoot" has the stigmal region reddish brown, or 'smoky yellowish,' and never at all greenish either when newly emerged from the gall or upon aging.

It seemed desirable in a circumstance so complicated to give, before presenting original data, the historical situation for the species under consideration, which develops in a cone-like gall on the black spruce (in which connection it was named *abieticolens* in 1879 by Thomas and subsequently merged by error with *abietis**), and migrates to the needles of the white pine (in which connection it had been previously named *pinifoliæ* by Fitch, 1858, and merged by error with *pinicorticis*† in 1869 where it has remained for 40 years in oblivion).

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* Fernald and Cooley, 34th Report Mass. Agric. College 1897, pp. 89-100.

† Shimer. Trans. Am. Ent. Soc. 2: 383.

CHERMES PINIFOLIAE IN MAINE.

On June 16, 1905, I first found winged *Chermes* in great abundance on the needles of white pine (*Pinus strobus*) at Orono. My notes for that date state that on some branches nearly every pine needle had a *Chermes* stationed near the tip with the head away from the tip. On some needles were three or four. Most of the specimens observed at this date were dead. A large cluster of eggs was found beneath the wings of each *Chermes*. Eggs brought in June 16 hatched June 26.

Immediate reference to Fitch's description gave such a striking agreement of my notes with his account of the egg laying habit of *Chermes pinifoliae* that I listed the collection under the name of that species. Mounts were made of the freshest specimens a few of which were still alive. These I took with considerable other material to Mr. Pergande the following winter and he kindly compared them with Fitch's type* of *Chermes pinifoliae* and stated that the type specimen was too imperfect to give a satisfactory basis of comparison but that in size and in such points as could be compared the two agreed and that he considered the specimens from Maine to be *pinifoliae*.

July 5, 1907, at Milo, Maine, I observed this species very abundant on the needles of white pine. The specimens were all dead at this date but they still adhered to the needles, on some of which there were as many as 14 or 16 in Indian file with their heads towards the base of the needle. This was in accordance with Fitch's observation "I have met with the dead females thus adhering to the leaves the first of July." Specimens of this collection were photographed as taken. See Fig. 127.

On June 14, 1909, a large number of black spruce twigs were brought to me with the statement that "almost every *cone* is infested under the scales and is abnormal in form." Some of these specimens are shown in Figs. 128 and 129. The infested growths at this stage were indeed so cone like that I took their cone-ship for granted until I read over Packard's discussion of *abieticolens* Thomas which he "found in abundance on the spruce in Maine, where it produces swellings at the ends of the twigs resembling in size and form the cones of the same tree." Dissection of the galls, of course, proved they were not abnormal *cones* but abnormal *shoots*.

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* Fitch's aphid types were originally mounted on card points on pins. A few of these came finally to the U. S. collection where they were removed and are preserved as balsam mounts.

The mistaken identity of the so-called "cones" seemed a good joke entomologically and as the collector of the galls is a plant morphologist perhaps not less so botanically.

Both the galls and the *Chermes* in them are distinct from *abietis* and there seems no ground for doubting that this species is *abieticolens*.

Some of the more advanced galls of *Chermes abieticolens* were opening on date of collection, June 14, and by June 21 fresh *Chermes pinifoliae* were on the needles of White Pine everywhere in the neighborhood of Orono. Others were sent in from other parts of the state a little later. Accompanying such specimens from Gilead vicinity on June 25 "millions of the flies on white pines" were reported.

As the disappearance of the emerging *abieticolens* from the spruce coincided exactly in time with the appearance of *pinifoliae* on the white pine and as there was no apparent difference in the *Chermes* in these two situations the conclusion was obvious enough and careful microscopic comparison was, of course, made. There was no difference between the two discoverable in any structure submitted to this sort of examination. The freshest of the specimens on the white pine had of course to be used for the comparison.

A check migration test was made June 22. A lot of galls from the black spruce were placed in a cage with fresh twigs of various conifers. On June 25, more than 200 individuals had settled on the white pine where they remained with their eggs. Although specimens were found crawling over some of the spruce twigs supplied them no individual settled and oviposited except on the white pine. This was more overwhelming preference than is usual with a cage test, for often in confinement a few stray specimens oviposite amiss, as it happens also to insects in the open. Perhaps if the test had been prolonged some of these would, but three days with the uniform result of 200 to 0 seemed sufficient.

In confinement, as in the open, these *Chermes* settled on the pine needles with the head toward the base of the needle. Out of the thousands seen this season only very rarely was one found headed in the other direction. In confinement as in the open this species did not "oviposite" in the usual sense of the term, as the eggs were not expelled. As Fitch himself accurately recorded what I have observed three seasons (1905, 1907, 1909*) "the females of these insects do not extrude their eggs. Clinging closely to the leaf with their heads towards its base, they die, their distended abdomens appearing like a little bag filled with eggs. The outer skin of the abdomen soon perishes and disappears, leaving the mass of eggs adhering to the side of the leaf, but completely covered over and protected by the closed wings of the dead fly." Such an egg cluster comprises about 100 eggs.

The eggs of the *Chermes* which settled on the pine needles June 22-25, in the cage migration test recorded, were hatching July 3, in conspicuous numbers.

These young, the progeny of the migrants, settle at the tips of the new pine shoots where by the latter part of July their presence is rendered conspicuous on account of the white waxy secretion of the *Chermes*. This secretion gives a white woolly appearance to the infested portion similar to but much less dense than that of *pinicorticis* on the trunk of the white pine.

Where the infestation is heavy it causes a yellowish and sickly appearance of the new growth which is thus considerably stunted. As will be seen by Fig. 132 taken July 23, 1909, the new needles are not at this time full grown. The new needles on twig photographed were yellowish for a part of their length and the whole tip of the twig had an unhealthy appearance.

It will be seen from the date of the flight of this species from the spruce galls to the pine, about June 15-21, that the pine leaves on which they settle to oviposite are those of previous years growth, that is, the needles of 1909 have not started sufficiently for the *pinifoliae* of June 1909 to use.

This fact is in contrast with a second species, *Chermes floccus*, migrating from black spruce galls to pine needles late in July and ovipositing both on old growth and new growth needles. There is no reason for confusing *pinifoliae* with this second species as the discussion of the latter will make plain.

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* I am not able at present to state whether there may be any significance in this once in two years collection or not. I had not been paying any particular attention to *Chermes* and they may have been present in considerable numbers the other years also, and I had merely neither collected nor recorded them. The notes as they stand suggest a two year cycle but no observations as regard to this are yet available.

On May 19, 1908, I found *Chermes* pupae common on terminal shoots of white pine. My notes for this collection read: "The pupae are massed close to the tip of the stem or at the base of needle cluster on some stems, and on others they occur singly at the same locations. They are downy enough to be noticed but are not very flocculent."

I collected a considerable number of twigs and the next day many of the pupae molted and an abundance of winged adults were secured. These I listed at the time as *pinifoliae*, and on going carefully over this preserved material this fall I can see no reason to separate it from the species which matures in the black spruce gall about the middle of June. Antennal, wing, and leg characters are apparently identical and the gland areas are so faintly indicated as to ally it with this species and separate it from any other taken in Maine.

These mid-May *Chermes pinifoliae* are, I believe, the return migrants from pine to spruce, but I have not observed this migration. They are not the generation that oviposites on the pine needles, however, as this is done by the migrants from the spruce. This collection, May 19, it will be seen, is in accordance with Fitch's statement that he had "noticed the same insects on the leaves in full life and vigor the middle of May."

It will be seen from the dates of the migrants that either the time which *pinifoliae* spends on the spruce is very short—four to six weeks—or that a two year cycle is required. It is not at present possible to say which is the case.

The galls are uniform, regular, and cone-shaped in form. In length they vary when full grown from about three-fourths to one and one-half inches. Under the stimulation of the *Chermes* the new growth at the tip of the twig is modified and the twig tip develops into a cone-shaped object. The stem itself is not much swollen. Each needle becomes a scale, broadest at the middle and concave on the inner surface. Beneath each scale-like leaf a single Chermes develops. Packard states that in the gall of *abieticolens* "each leaf bud is enlarged having an *Adelges* under it" which statement in itself would distinguish such a gall from that of *abietis* each cell of which contains not "*an*" but *many* individuals. A single gall of *pinifoliae* not under average size which I dissected was found to be composed of 139 scale-like leaves under each of which was a single pupa.

The gall when young is slender, about the same length as the young cone and often about the same purple color. Fig. 129 shows a black spruce twig with a single young cone at *A*, the tip of which is unfortunately broken; at *B* are four normal spruce tips; at *C* are four young galls of *pinifoliae*. This photograph shows very well the distinguishing feature of these three growths, the normal shoot, the modified shoot or *Chermes* gall, and the normal cone.

Fig. 128 shows a fully developed gall which at this stage is green. After the galls lose their first purple color they remain green until the time of the emergence of the migrants. Fig. 130 shows the normal cone at *A* which at this stage is purple, at *B* the normal shoot which is green, at *C* the deserted gall which is bright reddish brown. After the gall is deserted the gall leaves flare out from the stem, leaving the chambers open wide. About this time the gall becomes a bright reddish brown, that is the galled terminal shoot dies in this characteristic way.

Pupa. The full grown pupa (June 14) is dark reddish brown with thorax somewhat lighter than head and abdomen. Legs and antennae dusky. Body lightly threaded with short wax fibers, giving body a downy appearance.

Winged Female. Fig. 108. The newly molted migrant, before the wings are expanded, is glistening reddish brown with pellucid legs and antennae. The crumpled wings are distinctly yellow. The wings when expanded are smoky, the stigmal region is yellowish or reddish brown. The migrant by the time it has reached the pine needles is very dark, with "its abdomen dusky red and slightly covered with fine cottony down." The antennae and legs are dark. In size these migrants vary greatly as indeed do all the *Chermes* listed in this paper. The total length of body of this form ranged from 1.7 mm. to 2.9 mm. (.066 in. to .11 in.) the latter measurement being for the larger individuals with their abdomens fully extended. The wing expanse varies also, the average being about 8 mm. There is nothing especially striking in regard to the venation. The characteristic curves of the veins have been faithfully reproduced (Fig. 108). At the junction of *Sc* with costal margin the wing creases a little and a decided angle occurs at that point in the wings of this species except when they are newly emerged. This angle is more pronounced for this species than any other of these Maine species, though the same tendency is often shown by others to a slighter degree. The drawing was made from a wing of a newly emerged individual and this costal angle not indicated.

The most distinctive characteristic in the wings of *pinifoliae* is the decided arch of the costal margin of the fore wing and the almost circular curve of the hind margin of the hind wing. The shape of the wings alone would separate this species from the other five developing in spruce galls in Maine. Packard's figure of *abieticolens** gives the characteristic outline of this peculiar wing which alone would serve to separate it from *abietis*. The legs are very stout.

The antennae (Fig. 109) are 5-jointed, the segments stout, III, IV and V are approximately subequal in length. III and IV resemble each other closely both as to shape and sensorial areas. V has the curve of the outline less abrupt, and the sensorial area larger. Terminal hairs four or five in number and slender (Fig. 109a). The sensorial areas as well as the shape of segments and reticulations are shown in the figure of antenna more distinctly than verbal details could indicate.

The wax pores of this species are more difficult to find than on any of the other species recorded in this paper. Even in specimens fairly well cleared the gland areas were not always evident. However, from a large series of mounts of specimens cut transversely giving the clearing fluids every opportunity, the gland areas (Fig. 108) were found to be consistently as follows: head with an area of two transverse groups on anterior margin nearly coalescing, an area of two transverse groups at posterior margin; prothorax with an irregular lateral area, a median anterior area of two groups, and a row of 4 groups near posterior margin; mesothorax with a lateral group on anterior margin and a median area of two groups on posterior portion

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* Insects Injurious to Forest and Shade Trees.

of the lobes; metathorax with a median area of two groups corresponding to the median rows of the abdomen; abdomen with median area in two groups (or frequently merging) on segments 1-7, and a lateral group on segments 1-9 (merged on the ninth). In addition to these there occurs between the lateral and median groups on segments 1-4 a very small group of two or three pores usually separate from the median pores, but sometimes merged with them. Most, if not all, of these wax pores would easily be overlooked and the fact that this species has its abdomen only "slightly covered with fine cottony down" indicates that the glands are not so functionally active as those of other species.

Remedial Measures. There would seem to be no practical method of combatting this insect in forest growth. With ornamental trees, however, the galls could be removed from the black spruce previous to the emerging of the winged form. Also if the species proves constantly troublesome it might be desirable not to plant the white pine in the vicinity of black spruce and *vice versa.*

Spraying with whale-oil soap (1 pound to 2 gallons of water), would probably destroy the young on the white pine shoots, but it is doubtful that this would be usually worth while in Maine where Syrphus flies abound. The larvae of these, little light colored maggots, have been found to feed industriously on the young Chermes. So numerous are these beneficial maggots at times in the midst of the white waxy secretion of the Chermes that they are sometimes mistaken by people submitting them for determination as the cause of the trouble.

Note: The foregoing evidence will make it clear enough that Shimer was in error in considering the winged specimens which he reared from *pinicorticis* to be *pinifoliæ.* That Shimer found winged *pinicorticis* "very plentifully" on the pine leaves would be natural enough for at the time of emergence the winged forms are sometimes abundant on all parts of the tree. I have seen them in considerable numbers resting on pine needles apparently just before flight, but never fixed as described by Fitch as characteristic of *pinifoliæ.* Observers of *pinicorticis* have accepted Shimer's conclusions that his *Chermes* .025 inches long which he bred from pupal *pinicorticis* was the same as *pinifoliæ* described as .08 inches long, in spite of the fact that they have had to contradict Fitch's explicit observations in regard to the very characteristic habits of *pinifoliæ.* With the meagre descriptions of the early aphid records many such mistakes are scarcely avoidable, in absence of the species itself. Fitch's comments on *pinifoliæ,* however, are distinctive enough so that with his species in hand it no longer seems "singular" and "unfortunate" that he described *pinifoliæ* as distinct from *pinicorticis,* but rather singularly interesting that this species had not been rediscovered long ago.

To see that Fitch's much discussed description of the wing of *pinifoliæ* agrees with fig. 108 it is only necessary to translate it to modern parlance "The rib vein (Rs) runs straight to the outer margin forward (proximad) of the tip, it gives off from its middle on the outer side a very oblique branch (Sc) which runs to the outer (costal) margin, its tip producing a slight angular projection* to the edge of the wing, and the whole space (stigma) on the outer side of the rib vein (Rs) beyond this branch (Sc) is more opake than the rest of the wing and of a smoky yellowish color. From its inner side the rib vein (Rs) sends off three simple oblique veins, the last one (M) of which ends in the extreme tip of the wing. The hind wings have an angular point (for hooks) on their outer side (costal) beyond the middle, and a longitudinal rib-vein (Rs) which forward (proximad) of its middle sends off a branch (M) almost transversely inward (caudad) with its tip curved backward (distad)."

1858. *Chermes pinifoliae* Fitch. *Trans. N. Y. St. Agr. Soc.* for 1857, *Vol.* 17, 1858, *p.* 741. Republished in 4*th Rep. Ins. of N. Y.* 1859 *p.* 55.
Description of winged form.

1862. B. D. Walsh. *On the Genera of Aphididae Found in the U. S.* Species listed only.

1869. Henry Shimer. *Trans. Am. Ent. Soc., Vol.* 2, *p.* 384. Winged forms of *pinicorticis* mistaken for *pinifoliae.*

1879. Cyrus Thomas. *Eighth Rep. St. Ent. of Ill., p.* 156. Quotes Fitch's description.

1881. A. S. Packard. *Insects Injurious to Forest and Shade Trees. p.* 118. From Fitch.

1884. Herbert Osborn. *Bulletin No.* 2. *Iowa St. Agr. Coll. Dept. of Ent.* Follows Shimer's error in considering winged *pinicorticis* to be *pinifoliae.*

1885. J. A. Lintner. *2nd Rep. St. Ent. of N. Y., p.* 180-187. Follows Shimer's error in considering winged *pinicorticis* to be *pinifoliae.*

1890. A. S. Packard. *Fifth Rept. U. S. Ent. Comm. p.* 805. Fitch's description quoted, without comment.

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* See page 286 for comment.

1898. Storment. *Rept. Ent. Ill.* 20; iii-xxiii. Follows Shimer's error in considering winged *pinicorticis* to be *pinifoliae*.

1901. W. D. Hunter. *Iowa Agric. Coll. Exp. Sta. Bull.* 60. *The Aphididae of North America.* Lists *pinifoliae* as a synonym of *pinicorticis*.

1909. Edith M. Patch. *Annals of the Ent. Soc. of Am. Vol. II. No. 2.* Discussion of tracheation of wings of *Chermes pinifoliae.* Pp. 107, 111, 116 and figs. 26-30.

1909. Edith M. Patch. *Me. Agric. Exp. Sta. Bul. No.* 171. Economic treatment giving main features of life history of *pinifoliae* and stating that *abieticolens* is the gall generation of the same species.

1909. Edith M. Patch. Psyche Dec. 1909, pp. 136-137.

Chermes abieticolens.

1869. A. S. Packard. *Guide to the Study of Insects, p.* 522. Brief description with figures of this species recorded as a species of *Adelges* occurring in abundance on the spruce in Maine. Some good characters of gall also given.

1879. Thomas. *Rept. Ent. Ill.* 8: (*III of Thomas*) *p.* 156. Species named provisionally as *Chermes abieticolens* and statement made that it is certainly distinct from *abietis*. Refers to Packard.

1885. J. A. Lintner. *2nd Rep. St. Ent. of N. Y., p.* 185. Refers to Packard and Thomas.

1887. Oestlund. *Aph. Minn.* Species listed.

1890. A. S. Packard. *Fifth Rep. U. S. Ent. Comm. Adelges abieticolens* Thomas. Original account and illustration copied.

1897. Fernald and Cooley. *34th Report Mass. Agric. College, pp.* 89-100. *abieticolens* merged with *abietis* by error on the basis that in response to "about five hundred circular letters sent to different persons in the U. S. and Canada, only one species of *Chermes* was received." Excellent account of *abietis*.

CHERMES ABIETIS Chol.

This common European species has been variously designated as "The Spruce Gall-louse"*, "The European Spruce Bud-louse"†, "The Yellow Chermes"‡, "The green-winged Chermes"** and the gall has been aptly called the "pine-apple gall" on account of its form.

This species has been for a good many years annually abundant on the Norway and white spruces on the campus of the University of Maine. I have collected the gall and the insect at various stages frequently since the fall of 1903, without giving the species any especial study except to compare my own observations with published accounts.

Confusion in the literature of this species both in this country and in Europe has existed on account of other species having been confounded with it. Because of this it may not be out of place to present my own notes, though probably containing no new observations, in connection with the photographs of the galls and the drawings of the species which they concern.

The Gall. Fig. 137. The galls of *abietis* vary in size from about ½ inch to 1 inch or more in length. They occur at the base of terminal shoots and do not as a rule kill the twig. Where they are numerous they cause serious deformations of the branches, and small trees are sometimes ruined by their presence. Such galls are not only very abundant on Norway spruces but they are troublesome on the native white spruce in Maine. This season (1909) a single white spruce 3 feet tall had more than 990 fresh galls upon it. The growing galls are green, with the closed mouths of the cell marked by a ʌ-shaped red line. The shade of this line varies from purple to brick red in different galls and at different times. The galls resemble in form a little pine-apple, each section being represented by a needle much enlarged at the base and little if at all at the tip. The relation of the galls to the twig on which they grow is shown in the longitudinal sections in Figs. 138 and 139. It will be seen that in some cases the gall entirely encircles the twig which continues its growth from the apex of the gall, while in others the gall is produced in a one sided manner only partly encircling the twig. The cells of the gall are closed. A sample gall about ¾ inches long contained about 50 cells each holding from 8 to 12 nymphs. This count was made August 13.

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* 34th Report Mass. Agric. College.

† Packard, 5th Report of Ent. Comm. page 853.

‡ Die Coniferen-Läuse Chermes. Prof. N. Cholodkovsky. 1907.

** Me. Agric. Exp. Sta. Bul. 171.

About the middle of August at Orono the mouths of the cells open and the pupae emerge to molt.

Nymphs, the Gall Generation. Specimens taken from galls June 23, 1904, are recorded as greenish yellow. July 24, 1909, nymphs are recorded as very pale yellow covered with white pulverulency. Molted skins attached to caudal extremity were filled with liquid so as to retain their shape. Many nymphs had two such molts attached so that three successive stages of the insect were in line. The excreted liquid being largely disposed of in this manner, the cell wall of *abietis* is clean and dry, a condition made further possible by a slight covering of waxy powder.

Pupae. Body length of full-grown pupa 1.9 mm. Specimens taken from galls on Norway spruce August 4, 1909, were very pale yellow, slightly pulverulent. Others taken from galls on white spruce August 17, 1909, were a little darker yellow and the finely-pulverulent abdomen had a slight rosy tint. The pupae leave the galls before molting. The time of most plentiful emergence is from about the middle to the last of August for the vicinity of Orono, though the galls in more exposed sunny places are about a week earlier in opening than the average shaded ones. The pupae creep from the open cells of the galls in a sluggish manner and often rest in Indian files on the needles near the gall, where they molt and become the winged individuals. The cast skins remain in white rows upon the needles for some time unless dislodged by rain. See Fig. 140.

The wax pores for the pupa are: (Fig. 117) head with an anterior group of pores near base of each antenna and two median groups at posterior margin; prothorax with lateral gland area, an anterior median pair of groups, a small group (4 pores) between the lateral and median ones, and four groups near posterior margin of prothorax; mesothorax with an anterior lateral area; metathorax with two separated median groups; abdomen with small and widely separated median groups on segments I-VI, those on I being composed of about 6 pores, those on II of 3 and those of III-VI of 2 each, a very small group of lateral pores occur on segments II-IX (merged to a caudal group on IX), and about half way between the median group and lateral margin an additional group of about 3 pores occurs on segments I and II. The smallness of these inconspicuous groups is correlated aptly with the fact that this is not a flocculent species, the wax secretions not exceeding the pulverulent condition. Fig. 117 shows a pupa a short time before the final molt.

Winged Oviparous Form. Fig. 115. The freshly molted individuals, August 19, 1909, have a golden brown body, the thorax, except the dorsal lobes, slightly lighter than abdomen, lobes of thorax dark, head dark, wings with whole stigmal area and margin a decided and conspicuous green, the remainder of the wing being white with a slight yellowish green tint. As the individual ages the coloring becomes darker, though the wings retain their characteristic green color. Length of body 1.7 to 2 mm., wing expanse 6.mm.

The areas of the wax pores (Fig. 115) are much as in the pupa except for the abdomen which is as follows: I with median groups comparatively large and merged, II median groups separated and composed of 2 pores each, V with two small groups between median ones referred to. I-VIII with distinct lateral groups on darkened area, III-VI with small groups of 2 or 3 pores each midway between median and lateral groups.

The wing veins of this species have, as with the other five discussed in this paper, a fairly constant characteristic trend which is shown in Fig. 115. First A of the fore wing is seen to be considerably arched.

The sensorium of each of antennal joints III-V is confined to the distal half of the joint and extends not more than half way around the joint. These three joints are much alike in general appearance. III is noticeably shorter than IV while IV and V are subequal. The usual group of smaller sensoria occurs on V and there is nothing striking about the 4 or 5 terminal hairs. Fig. 116.

Apterous oviparous form—winter female or stem mother. May 7, 1906, I observed these young females of the winter generation, minute and slightly downy clinging close to the buds or in the axle of the leaves on Norway spruce. May 31, 1906, the females were very plentiful and were readily detected on account of the little white flocculent mass surrounding her and her recently laid eggs. One such egg cluster contained about 140 eggs and the female was not through ovipositing.

The life cycle for *abietis* based upon the writer's observations is briefly as follows: Galls open about mid-August and fully grown pupae emerge and molt within a few hours becoming the winged form which deposits a cluster of 40 to 50 yellow eggs on a spruce needle. The eggs are extruded from the abdomen but the parent *Chermes* remains over them until dislodged after her death by wind or rain. The winged form often oviposites near the gall from which it emerges. A different species of host plant is never sought by this *Chermes.* In about two weeks the young "stem mothers" hatch from these eggs and seek a protecting crevice in the surface of the spruce bud where they can spend the winter. These wingless forms develop in the spring and become full grown about the last of May when they lay a cluster of 140 or more eggs. From these eggs hatch the young that inhabit the gall and are known as the "gall generation" with which we started the cycle.

For a further account of *abietis* the reader is referred to the 34*th Report of the Mass. Agric. College*, 1897, and to *Die Coniferen-Läuse Chermes* by Prof. N. Cholodkovsky, 1907.

Remedial Measures. Spraying the trees in April with whale-oil soap solution (1 pound to 2 gallons of water) has been reported as effectual. (34th Report Mass. Agric. College). The practice of removing and burning the galls will serve to control this species sufficiently on ornamental trees. At Orono great numbers of the winged forms are caught in spiders webs that are spun irregularly over the spruce twigs.

Bibliography. It does not seem practical to attempt a bibliography of *Chermes abietis* for United States. That various other *Chermes* have been confused with this species is certain, but to what extent it is often impossible, on the basis of the references, to be sure. The illustration in Bulletin 56, West Virginia Agricultural Experiment Station 1899 of the "Galls and deformed twigs of the spruce gall louse" (Fig. XXXI, page 261) does not figure galls of *Chermes abietis* but those of some other *Chermes*, possibly of *similis.*

In the Spruce Gall-louse *Chermes abietis* Linn. by Fernald and Cooley (34th Report Mass. Agric. College, 1897) is presented carefully the life history and habits of this species. The figure of the gall Plate II in that paper is the characteristic *abietis* gall and the wings on the same plate show the typical curves of the veins of this species. The record of *abietis* from Colorado (page 4 of Author's separata p. 92 in 34 Report) however applies to *Chermes cooleyi* (See Gillette *Chermes of Colorado Conifers* page 3), and *abieticolens* of Packard and Thomas is by error in that publication considered to be the same as *abietis*.

CHERMES LARICIATUS Patch.

A gall resembling that of *abietis* very closely in size and form and found, like that of *abietis*, on white spruce was taken in the vicinity of Orono by Mr. William Woods, July 28, 1909. Fig. 141 shows two of these.

The galls. Like the galls of *abietis* they are not terminal on the twig and the tip of the twig extends out from their apex when they encircle it, or along one side of the gall when they do not, just as with *abietis*.

The galls were mature on date of collection. The needles of the gall are green at this season. Conspicuous wide russet lines mark the closed mouths of the galls which gives the gall a general russet color. The needles of the gall are much shorter than is usual with *abietis* on the Norway and White spruces and it is thus a little more pine-apple like in form than *abietis*. Many of the galls were opening at the time they were collected, and the pupæ walk out from the open cells before they molt, as do *abietis*. The galls become dry and brown soon after they are vacated. The cells are not as shallow as those of *abietis*.

The pupa. (Fig. 122). Described from forms just leaving the gall before the last molt. Length of body 2 mm.; head, prothorax and abdomen light reddish; thorax yellowish green; wing pads dark green; ventral prothorax and thorax yellowish green; legs and antennae greenish. The areas of wax pores are well defined; head with anterior area between antennae, and four posterior groups; prothorax with a large lateral area, an anterial row of 4 groups, a posterior area of 2 groups, and a broken line of 4 groups between the anterior and posterior groups; mesothorax with a very large anterior lateral area and a row of 4 groups across the middle of the segment; metathorax with a very large lateral area about the size of that of the mesothorax, and a row of 4 well defined and separated groups which are in line with those of the abdomen; abdomen with lateral groups on I-IX (merged to caudal group on IX), I-VI with a dorsal row of 4 groups on each segment, the median ones being largest but not merged.

The Winged Oviparous Form. Migrant. (Fig. 118). Newly molted individuals have prothorax and abdomen light yellowish brown, head and thoracic lobes dark, legs and antennae greenish, wings decidedly green with yellow proximal portion The individuals, of course, grow darker as they age. Body length about 1.9 mm.; wing expanse 6 mm. to 6.2 mm.

The well defined areas of wax pores are: head with 2 distinct anterior groups and 2 large and separate posterior groups; prothorax with the usual lateral area, a row of 4 anterior groups, and 2 posterior groups widely separated; mesothorax with two median distinct groups; metathorax with two median groups separate and in line with the median groups of the abdomen; abdomen with median groups on segments I-VI well defined and widely separated, well marked lateral groups on segments I-IX (merged to caudal group on IX), and a small group between the lateral and median groups on III-VI.

The antennae (Fig. 119), is more like that of *abietis* than any of the other species of this paper, but the outlines of the joints are less abrupt, the curves of the sensoria are more regular, and V is typically longer than IV. III and IV are about subequal.

The wings resemble those of *abietis* but are distinct enough. 1st A of the fore wing of *lariciatus* is less strongly arched and M of the hind wing is a heavier vein than that of *abietis* and strongly curved with the convexity distad.

July 31, 1909, this species was found to be common on the needles of larch everywhere in the vicinity of Orono. The migrants from the white spruce galls settled on the larch needles and oviposited. The eggs are extruded and not retained in the abdominal cavity as with *pinifoliae*, and the parent is more easily dislodged even than *abietis* and soon drops from the egg mass. There are from 50 to 75 beautiful green (paler than larch green) eggs in a cluster. (Fig. 121). They are slightly pulverulent. The glimpse through a glass at this little *Chermes* with the green eggs showing through her transparent wings is one of the prettiest sights of the insect season. Fig. 120 gives the position of this species when oviposition is nearly finished. The migrants settle on the larch needle either with head toward base of needle or toward tip, apparently indifferently.

On July 31, 1909, opening galls of this species were placed upon sprigs of conifers in cage. The twigs were in vials of water so that they remained fresh. On August 3 the individuals that oviposited were counted with the following results:

Picea rubra Dietr	Red spruce	0
Picea mariana (Mill.) B. S. P.	Black spruce	0
Picea abies (L.) Karst	Norway spruce	1
Picea canadensis (Mill.) B. S. P.	White spruce	4
Pinus strobus L.	White pine	0
Pinus sylvestris	Scotch pine	0
Thuya occidentalis L.	Arbor Vitae	0
Abies balsamea (L.) Mill.	Balsam fir	4
Larix laricina (Du Roi) Koch	Larch	69

The preference for larch speaks for itself. Whether the other ovipositions have any significance or are merely accidental it is, on the basis of this one test, impossible to say.

Whether *lariciatus* may be the same as *laricifoliae* Fitch I have not been able to decide. There is nothing in the brief description of Fitch's to preclude this possibility. Fitch's color description does not agree in all respects with my notes for *lariciatus* but these were made from specimens immediately after molting and would not be the same as an older specimen. The italisized portion of the original description for *laricifoliae* Fitch which is here quoted entire would apply very well to *lariciatus*. "*Solitary and stationary upon the leaves, extracting their juices, small* black shining flies *0.10* (*inch*) *long*, having the abdomen dark green, *the legs obscure whitish, the wings nearly hyaline with pale brown veins and the large stigma-spot upon their outer margin beyond the middle more opake and pale green.* This is closely like the Pine Chermes, No. 267, but *has the wings more clear, and differs also in some of the details of its colors.*"

So far as I can judge some of the records referred to *laricifoliae* in this country really concern *consolidatus* which is certainly not *laricifoliae* Fitch. It is not improbable that *lariciatus* may prove to be the European *viridis* Ratz. as discussed by Professor Cholodkovsky in *Die Coniferen-Läuse,* 1907. The galls of *viridis* Figs. 1 and 8 in that publication very well picture the galls of *lariciatus* and the host plants are identical.

As the specific characters on which I have laid most stress, antennae, wings and wax gland areas of the winged forms, are not given in so much detail in European publications as the structure of the apterous forms, the figures do not emphasize the same points and the only basis for comparison would be determined European material which may perhaps be possible to secure.

CHERMES CONSOLIDATUS Patch.

July 20, 1909, in the vicinity of Orono Mr. William Woods collected from black spruce some pink and green galls resembling those figured by Professor Cholodkovsky in *Die Coniferen-Läuse Chermes* 1907 for *Chermes strobilobius* Kalt. The flesh of the gall on the surface is a delicate pink, the needles of the gall, much stunted, are a delicate green. Some of the galls collected on the same day were pale green instead of pink. The galls (Fig. 145), are about one-half inch long or less and are terminal. The cells of the galls contained dark red nymphs which were flocculent rather than merely pulverulent, and the cell walls were also covered with the flocculent secretion.

Specimens began to emerge from these galls in the laboratory July 30, and galls found out of doors on red spruce were opening about the same time.

Opening galls of this species were placed in a cage on twigs of red spruce, black spruce, white spruce, Norway spruce, arbor vitae, white pine, Scotch pine, hemlock, balsam fir and larch. In a few days a count of ovipositing individuals was made and it was found that they had laid eggs *very sparingly* on each of the four spruces and balsam fir—1 to 5 specimens on each plant. 9 to 12 eggs were deposited in a mass under the wings. Most of the individuals died without ovipositing at all. This test certainly gave no dependable data, nor did I chance upon this species ovipositing out of doors. The galls in this vicinity were not numerous and the species is very small.

I have taken, however, on June 20, 1909, and about the same time previous years small *Chermes* pupae developing at the base of larch cones in flocculent matter. When these molt they prove to be brown bodied with a caudal flocculent tuft and greenish wings. These winged forms I am unable to separate on microscopic comparison from *consolidatus* (Figs. 123 and 124), and think that there is no reason to doubt that they are the same species, and that the larch and spruce are alternate hosts of *consolidatus*.

Whether they prove to be *strobilobius* Kalt. can only be ascertained by comparison with authentic European material which is not at present available.

Pupa. The pupa, described from specimens removed from spruce galls. -(Fig. 125). Body dark red and flocculent, the larger ones 1.2 mm. long. Areas of dorsal wax pores; head with large groups at anterior and posterior margin; prothorax with lateral areas, a row of 4 large anterior and 4 large posterior groups; mesothorax with a curved transverse row of six well defined groups, the outer ones forming the usual anterior-lateral groups, metathorax and abdominal segments I-VI with transverse rows of 6 groups each, VII-IX with only the marginal group. Fig. 125 was drawn from a pupa in its last stage but sometime before it molted. Later the conspicuous circular space about the gland openings is not so discernable.

The Migrant from the Spruce Gall. (Fig. 123). Length .9 mm.-1.3 mm.; wing expanse 3.5 mm.-4.0 mm. The wings of this species are very rotund. The veins in the fore wing are usually like those given in fig. 123 though frequently they are straighter. M in the hind wing usually curves with the concavity distad though sometimes this vein is nearly straight.

The most striking structural distinction between this and the other 5 spruce *Chermes* is in the antennae. The constrictions between joints III, IV, V are very inconspicuous so that these joints from some positions appear almost to be consolidated into a single long terminal joint. It was this character that suggested the specific name. The antennae of *consolidatus* are distinctive in one other respect, two of the four terminal hairs are developed into strong spines (Fig. 124a). This is not true of any of the other 5 spruce species.

Apterous oviparous form on larch.

On August 1, 1909, apterous oviparous forms in woolly mass on larch twigs were common. Although the connection was not traced I believe these to be *consolidatus* Fig. 126 was drawn from one of this collection.

CHERMES FLOCCUS Patch.

Like *Chermes pinifoliae* Fitch, this species develops in galls on black and red spruce and migrates to the needles of the white pine to oviposite. Both the galls and the insects, however, of these two species are too distinct to be in any respect confused.

These galls (fig. 134) were first collected on black spruce at Orono, July 10, 1909. They resemble galls of *similis* Gillette but are more compact and better formed than any galls of *similis* which were taken this season in Maine. They occurred in great numbers in this vicinity on red and black spruce. They are terminal and comprise the total deformed shoot. In length they vary from about ¾ to 1¾ inches. The surface of the gall is green in some while some have a dark purple tinge near the base of each needle, giving the gall a purple cast. The needles of the gall are not much dwarfed and are a normal spruce green. Figs. 135 and 136 give cross and longitudinal sections of this gall.

On account of the loose structure of the gall, syrphus maggots were very abundant within, feeding on the *Chermes* nymphs.

The pupa remains within the gall until after the last molt and the winged migrant emerges ready for flight.

Pupa. (Fig. 112). Described from specimen removed from gall shortly before the last molt. Length of body about 1.8 mm. Head, antennae, wing pads and legs dark or dusky, prothorax and abdomen rather dull reddish, thorax yellowish red and paler than abdomen. Entire body pulverulent. Wax gland areas on prothorax, thorax and abdomen are plainly located under a Zeiss binocular, by warty appearance of live specimen. These areas are: head with 2 large anterior and 2 larger posterior groups; prothorax with prominent lateral groups, also 2 small median anterior groups and 2 large posterior groups; mesothorax with prominent lateral areas, large median groups and small anterior groups; metathorax with 2 median groups in line with these on head and pro- and meso-thorax and abdomen; abdomen with lateral groups on segments I-VIII, large median groups on segments I to VI and a row midway between the lateral and median groups on I to VI. None of the pore-groups are merged in the pupa.

Migrants from spruce gall to pine. (Fig. 110) 1.5 mm.-2.1 mm. long with wing expanse 5. 0-mm.-5.6 mm. Freshly molted individuals have a yellowish red body and pale buff wings. The antennae are characterized by the exceedingly large sensoria on joints III, IV, V. Each sensorium comprises the entire surface of the joint except the extreme proximal and distal portions and a narrow ridge connecting these. The constrictions between joints are abrupt. III and IV are subequal and V is longer and not so thick. The wings are rather narrow. 1st A in the fore wing curves, the convexity being distad. M of the hind wing curves, the concavity being distad. Large wax gland areas occur on head and the three thoracic segments. On the abdomen lateral groups are present on perfectly distinct darkened areas on segments I-VII, IV, V, and VI are transversely banded by wax pores across the dorsum. Merged median groups occur on I, II, III and on III a separate group (sometimes absent) midway between the median and lateral groups. I and II are without wax areas between the median and lateral groups.

These winged forms migrate, from the middle to the last of July near Orono, to pine needles where they oviposite .(Fig. 133.) The ovipositing females secrete considerable wax from head glands as well as over the rest of the body so that they are a decidedly flocculent and not pulverulent species. This character alone would distinguish them from *pinifoliae* and is chosen for the specific name on that account.

In the woods these migrants were found abundant on the white pine needles over egg clusters of about 40 eggs. Coming so much later in the season *floccus* finds both old and new growth pine needles available and deposits the egg mass indifferently on the old or new. *Pinifoliae* migrants occur in this region only on needles of previous years growth as they appear the middle of June.

Chermes floccus migrants are not so particular as *pinifoliae* as to which way they are headed, some migrants settling on the pine needles with head toward the tip and some with head toward the base.

Besides the out-of-door observation of the migrants on white pine, a laboratory test was given. July 19 a lot of galls from which *floccus* were emerging were placed in a cage among the following conifers which were kept fresh in vials.

July 21 migrants had settled and deposited egg clusters as follows:

Picea mariana (Mill.) B. S. P	Black spruce	0
Picea rubra Dietr.	Red spruce	0
Picea abies (L.) Karst.	Norway spruce	0
Picea canadensis (Mill.) B. S. P.	White spruce	5
Abies balsamea (L.) Mill.	Balsam fir	0
Tsuga canadensis Carr.	Hemlock	0
Pinus laricio Poir.var.*austriaca* Endl	Austrian pine	0
Pinus sylvestris	Scotch pine	0
Pinus strobus L.	White pine	92
Thuya occidentalis L.	Arbor vitae	0

July 21, two small tips of white pine alone were put with *floccus* galls. In 48 hours 57 *Chermes* had oviposited on one and 117 on the other. These eggs began to hatch July 28.

CHERMES SIMILIS Gillette.

On July 9, 1909, my attention was called to some scraggly twigs of Norway spruce which proved to be deformed by *Chermes*. These galls resemble somewhat those of *floccus* but they are less regular. Fig. 142 pictures these. Winged specimens were emerging from these galls on date of collection. A search of white, red and black spruces resulted in taking the same galls on all these. These galls are very loose in structure and syrphus maggots freely helped themselves to their contents.

Galls from all these spruces contained pupae practically ready to molt and become the winged form, and also a few very small apterous oviparous individuals which were laying clusters of eggs in little woolly masses. These apterous forms were also found with their eggs in woolly masses along the stem and in one case on the outside of gall of *floccus* (fig. 134.) They were reddish brown and were .5 mm. to 1.0 mm. long.

The winged forms from the Norway spruce out of doors were migrating. On the other hand, the winged ones from black spruce galls were settling and ovipositing freely on black spruce. They are a flocculent species and their wings showed dark against the woolly mass which covered their abdomens and egg clusters.

What the life-cycle relation of the apterous oviparous forms is to the migrants appearing and ovipositing at the same time I do not know. They are here considered as *similis* though their identity is not proven. The galls of *similis*, however, were the only ones discussed in this paper in which apterous oviparous forms were found. Professor Gillette also records apterous females and their egg clusters to be present in galls of *similis*.

A cage test as to preference of spruces of the migrants was made. July 9, galls from black spruce were caged with uninfested black, white and Norway spruces. By July 13 a few migrants had settled on the Norway and deposited but a decided preference was shown for the white spruce upon which they settled in plentiful numbers and deposited eggs, remaining for a time on the little white woolly masses.

July 9, galls from white spruce were placed with uninfested white, black and Norway spruces. A large majority chose the white spruce. The eggs of this species hatched in about a week.

On trees where the infestation was heavy the terminal shoots were sticky and the needles somewhat ruffled. (Fig. 144). In many places portions of the spruce needles turned whitish yellow giving a "blighted" appearance to the shoot.

The winged form (fig. 113), varied exceedingly in size, part of the emerging ones being about 1.0 mm. long with a wing expanse of 3.0 mm.-4.0 mm. while the majority were larger, ranging from 1.45 mm. to 1.7 mm. with a wing expanse of about 4.8 mm. Color of body reddish brown, wings a little smoky. Wings much as in *floccus* with the veins having a little more tendency to straightness. Antennae are more like those of *pinifoliae* than any other, both as to general shape of joints and the relative size of the sensoria. The wax gland areas are: head with dorsal surface nearly covered by the two anterior and posterior groups which nearly meet; prothorax with large lateral area, two anterior and two posterior groups; mesothorax with lateral anterior group and two very large median groups; metathorax with median groups extending nearly across the segment; abdomen with large groups on I-VI, median groups on I-VI being largest on I and graduated to smallest on VI; a group of wax pores midway between the median and lateral series on segments II-VI, those on IV-VI being much larger than those on I-II (the group on I, of 2 or 3 openings only, is sometimes missing).

Certain striking resemblances of this Maine collection to *similis* as described by Professor C. P. Gillette* led me to submit balsam mounts, galls and illustrations to him. On the basis of this data he stated that he is unable to find any good distinguishing characters to separate this Maine material from *similis*. Professor Gillette's courtesy in determining this species enables me to introduce *similis* from Maine.

CHERMES PINICORTICIS Fitch.

It frequently happens that trunks of the white pine in Maine are more or less covered by the white secretion of this minute *Chermes* which gives the bark a moldy appearance (fig. 146). The infestation has been particularly heavy during 1908 and 1909, but during the latter season so many syrphus maggots were present preying upon the *Chermes* that these natural enemies seem likely to check its increase.

Though I have reared the winged forms of *pinicorticis*, I have made no special study of this species. Whether it confines itself to the pine or possesses an alternate host is not known. I have found the winged forms resting in abundance on needles of infested small white pines, from which they took flight at the slightest jar. Whether their destination was another species of plant or merely another white pine, the present knowledge of this species does not give basis to state.

Either the wing or the antennal characters of *Chermes pinicorticis* would serve to distinguish it from any of the 6 *Chermes* discussed in this paper, though its minute size alone would prevent confusion.

The fullest account of this species is by Mr. Storment published in the Appendix to the *Twentieth Report of the State Entomologist of Illinois*. In Mr. Storment's paper, as in others on *pinicorticis* since Mr. Shimer by error merged *pinifoliae* with *pinicorticis* about 40 years ago*, the NAME *pinifoliae* is confused with *pinicorticis* both in the discussion and bibliography. It is evident from the context, however, that neither Mr. Shimer, Professor Osborn or Mr. Storment had observed the INSECT *pinifoliae* and for this reason the mistake in synonymy is very easily corrected.

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* Chermes of Colorado Conifers. 1907.

CONCLUSION.

The present paper deals with six gall forming *Chermes* of Maine conifers. The gall host and the alternate host, where there is one, has been in each case ascertained. No attempt has been made to follow the development of the winter generation. With three species of *Chermes* making galls on the white spruce and four on black spruce in one locality it is apparent that a detailed study of the winter generations could only be carried on satisfactorily on conifers raised from seed under quarantine.

A glance at fig. 134 where *Chermes similis* is seen ovipositing on galls of *Chermes floccus* is sufficient to suggest the confusion possible.

Both the galls and the winged individuals give characters sufficient to determine these six species, however, and these have been figured in each case.

Illustrations. The photographs published are selected from many taken by Mr. R. L. Hammond and have been a constant aid in recording permanently certain changing phases of the work of these *Chermes*, and have been a necessary part of the study. The drawings were made by Miss Charlotte M. King who spent most of the summer of 1909 at the Maine Agricultural Experiment Station. The structural details for each form figured were worked out independently by Miss King. During the same time the writer studied carefully with each species the arrangement and number of wax gland areas, the character of the antennal sensoria, wing characters and other significant points and the drawings as they stand record both Miss King's observations and my own critical interpretation, no detail that seemed important being left until sufficient material was examined for a mutual agreement.

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* For discussion see pp. 277-289 in this present paper.

Technique. At the time these species were studied, live material was available both for the pupae and winged forms. The general form of the individual was sketched first from live material and such structures as could then be ascertained were indicated. Details were studied and drawings completed from balsam mounts. Live specimens in some cases were mounted directly in the balsam and a few desirable results obtained for immediate use. In each case, however, a large series of mounts was carefully made for study, drawings, and photomicrographs. Total mounts were most satisfactory after the general method (modified according to size, readiness of penetration of the fluids, etc.) indicated as follows:

Killed in hot 98 per cent alcohol,
One hour in 80 per cent alcohol,
One-half hour in 98 per cent alcohol,
Ten minutes in 100 per cent alcohol,
Ten minutes in tolu.

Antennal details were taken from head mounts. Wings were in each species mounted separately. Where total mounts did not bring out clearly the wax gland areas of both thorax and abdomen, severed specimens were prepared to facilitate the more rapid and thorough clearing.

This detailed account of the method of preparation is given in order that the character of the material used may be recorded. Certain groups of wax pores, for instance, were not rendered visible in one or two species except in dissected specimens and in most, a large series was necessary to settle the number definitely. Some variation occurs in the size and arrangement of the groups of wax pores, but individuals figured and described represent the typical wax pore areas as they were seen. As the wax pores are often difficult to see the most convenient specific characters will be found in the wing and antennal characters which are distinctive and within slightly varying limits were constant, for the extended collection in this locality at least.

WING VEIN NOMENCLATURE.

For the nomenclature of the wing veins used here the reader is referred to *Homologies of the Wing Veins of the Aphididae, Psyllidae, Aleurodidae, and Coccidae, Annals of the Entomological Society of America,* June 1909.

NEW SPECIES.

It is possible that some of the species described as new may prove to be synonyms of European species, but as the inconvenience of a synonymy is so much less than the confusion of a composite species it seemed wise not to attempt comparison with European species until a careful study had been made of these *Chermes* as they occur in Maine.

The first brief descriptions of *floccus, consolidatus,* and *lariciatus* were published in Psyche, December, 1909.

CHERMES IN EUROPE.

Many important and admirable studies of *Chermes* species have been carried on in Europe by such careful workers as Blochmann, Börner, Cholodkovsky, Dampf, Dreyfus, Mordwilko, Nüsslin. A comprehensive review of this work with bibliography appeared in *Zoologisches Zentralblatt,* Dec., 1909. *Zusammenfassende Ubersicht. Die neueren Ergebnisse und Aufgaben der Chermes-Forschung von Prof. O. Nüsslin in Karlsruhe.*

HOST PLANTS.

The host plants in the following key are recorded solely on the basis of one season's careful collection in the vicinity of Orono. The list of host plants may need to be extended later but it is accurate so far as it goes. In recording the collections of the galls, the botanical distinctions between the red and black spruces has been observed, though entomologically these might pass for one species. *Chermes* at any rate does not pay any attention to the distinction.

KEY TO THE CHERMES OF MAINE CONIFERS.

A. Galls on black spruce (*Picea mariana* B. S. P.) and red spruce (*Picea rubra* Dietr.)

Gall terminal.

1. Gall conelike, needles modified to thin scales. Ripening mid-June. Migrants ovipositing on needles of white pine. (*Pinus strobus* L.) *pinifoliae.*

2. Scraggly deformed twig. Gall-needles not much abbreviated. Ripening first of July. Migrants ovipositing on spruce *Picea* sp. *similis.*
3. Gall usually well formed ¾-1¾ in. long. Needles not much abbreviated. Ripening mid-July. Migrants ovipositing on needles of white pine. (*Pinus strobus* L.) *floccus.*
4. Gall small, ½ inch or less, pink or pale green. Gall needles short. Ripening first of August. Species also found on larch (*Larix laricina* Koch.) *consolidatus.*

B. Galls on white spruce.
Gall terminal,
Scraggly deformed branch. Ripening first of July. Migrants ovipositing on spruce (*Picea* sp.) *similis.*
Gall not terminal,
1. Pine-apple shaped. Ripening last of July. Migrants ovipositing on needles of larch. (*Larix laricina* Koch.) *lariciatus.*
2. Pine-apple shaped. Ripening mid-August. Winged form not migrating to oviposite. *abietis.*

C. Galls on Norway spruce, *Picea abies* (L) Karst.
Gall terminal,
Scraggly deformed branch. Ripening first of July. Migrants ovipositing on spruce, *Picea* sp. *similis.*
Gall not terminal,
Pine-apple shaped. Ripening mid-August. Winged form not migrating to oviposite. *abietis.*

EXPLANATION OF PLATES.

Fig. 108. *Chermes pinifoliae* Fitch. Migrant from spruce gall to needles of white pine. Figs. 109, 109a. Antenna.

Fig. 110. *Chermes floccus* Patch. Migrant from spruce gall to needles of white pine. Figs. 111, 111a. Antenna.

Fig. 112. *Chermes floccus,* pupa developing in spruce gall.

Fig. 113. *Chermes similis* Gillette. Form which emerges from spruce gall. Figs. 114, 114a. Antenna.

Fig. 115. *Chermes abietis.* Form which emerges from spruce gall. Fig. 116. Antenna.

Fig. 117. *Chermes abietis,* pupa developing in spruce gall.

Fig. 118. *Chermes lariciatus* Patch. Migrant from spruce gall to needles of larch. Figs. 119, 119a. Antenna.

Fig. 120. *Chermes lariciatus.* Migrant on needle of larch with egg mass nearly completed and showing through the thin transparent wings. Drawn from living specimen.

Fig. 121. *Chermes lariciatus.* Egg mass on larch needle.

Fig. 122. *Chermes lariciatus.* Pupa developing in spruce gall.

Fig. 123. *Chermes consolidatus* Patch. Migrant which develops in spruce gall. Figs. 124, 124a. Antenna. Notice two strong terminal spines.

Fig. 125. *Chermes consolidatus,* pupa developing in spruce gall.

Fig. 126. *Chermes consolidatus?* Apterous oviparous form on larch.

Fig. 127. *Chermes pinifoliae* Fitch. Migrants from spruce to white pine needles.

Fig. 128. *Chermes pinifoliae.* Mature galls from black spruce still green and just before opening.

Fig. 129. Branch of black spruce. *A* cone with tip broken, *B* four normal spruce tips, *C* four young galls of *pinifoliae.*

Fig. 130. Tip of black spruce. *A* cone which is purple, *B* normal tip, *C* deserted *pinifoliae* gall which is bright reddish brown.

Fig. 131. Deserted galls of *Chermes pinifoliae* on red spruce.

Fig. 132. White pine showing injury to new growth by the young *pinifoliae* which may be located by the white secretion on twig at base of new growth. Photographed July 23, 1909.

Fig. 133. *Chermes floccus* Patch, migrants from spruce galls, ovipositing on white pine needles.

Fig. 134. Galls of *Chermes floccus* on red spruce. The white objects on the outside of the gall are waxy secretions of *Chermes similis,* apterous forms, which are ovipositing on *floccus* galls as well as on the twig.

Fig. 135. Gall of *Chermes floccus* from black spruce. Cross section. Fig. 136. Longitudinal section.

Fig. 137. Twig of white spruce with galls of *Chermes abietis.*

Fig. 138. Galls of *Chermes abietis* from Norway spruce. Longitudinal section of gall which does not enclose the whole twig. Fig. 139. Longitudinal section of gall which completely encircles the twig.

Fig. 140. Twig of Norway spruce. Show deserted gall of *Chermes abietis* and the white molted skins along twig and leaves.

Fig. 141. Twig of white spruce with galls of *Chermes lariciatus* Patch. Gall at right deserted. Gall at left not yet opened.

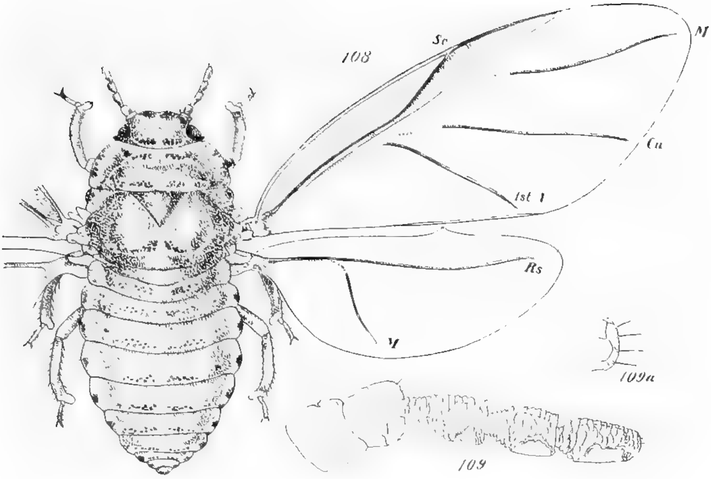
Fig. 142. Galls of *Chermes similis* Gillette on Norway spruce.

Fig. 143. Apterous flocculent oviparous females of *Chermes similis* showing white on stem of Norway spruce.

Fig. 144. Twig of black spruce showing injury to young of *Chermes similis.* Needles sickly yellow and covered with white flocculent secretion of the *Chermes.*

Fig. 145. Gall of *Chermes consolidatus* Patch on black spruce.

Fig. 146. *Chermes pinicorticis* Fitch on bark of white pine.



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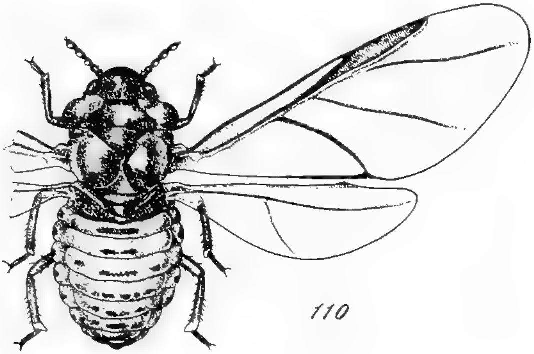

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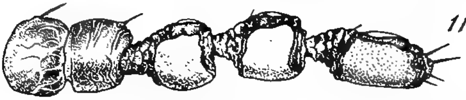

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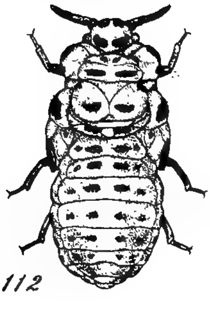

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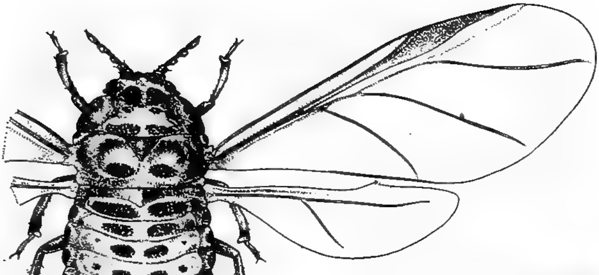

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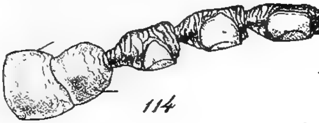

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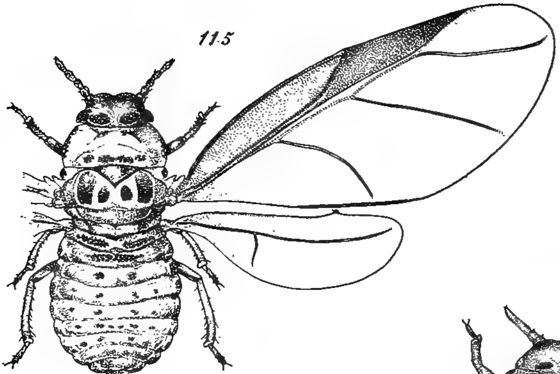

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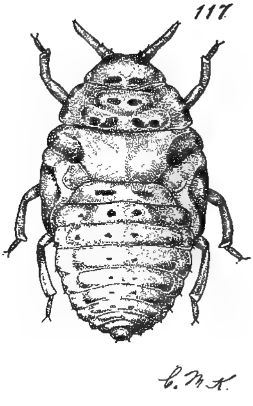

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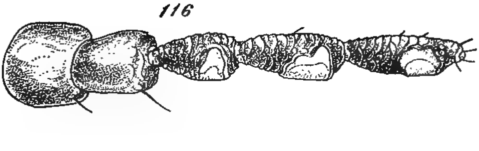

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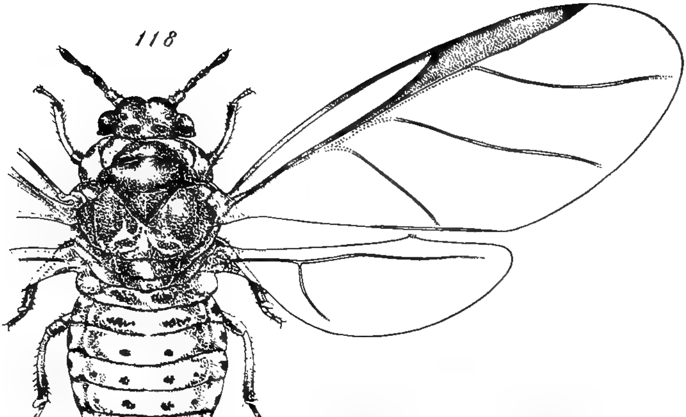

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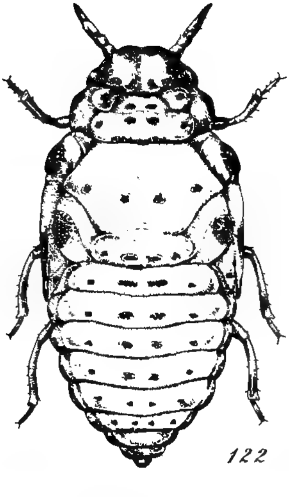

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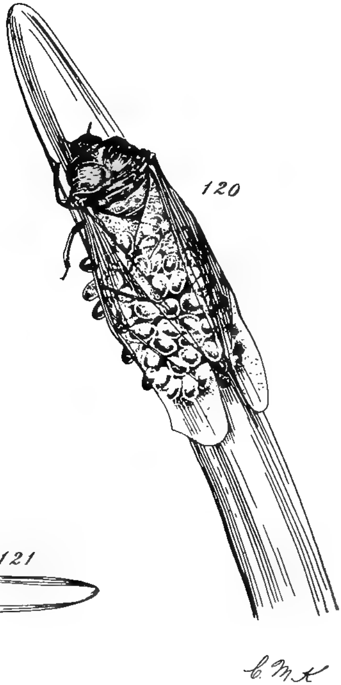

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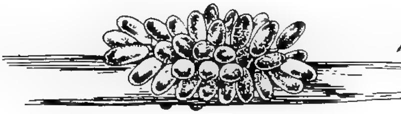

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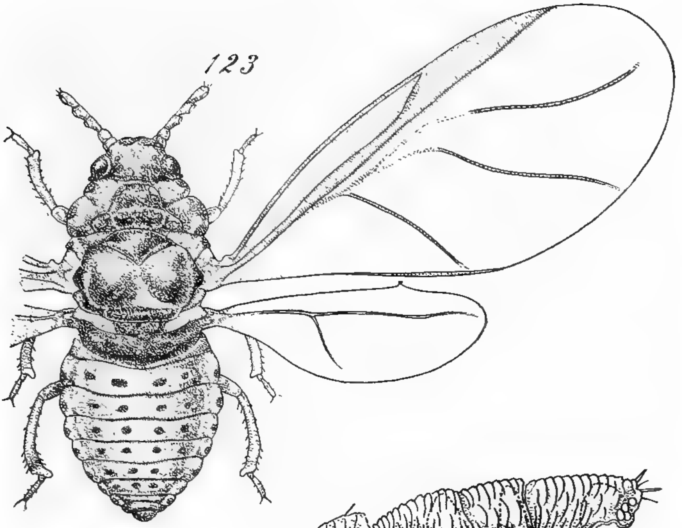
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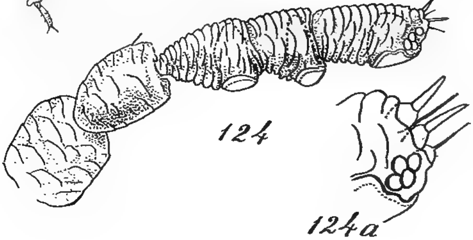
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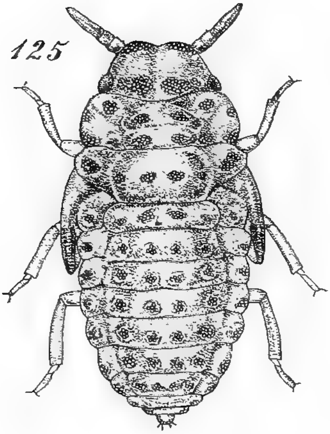
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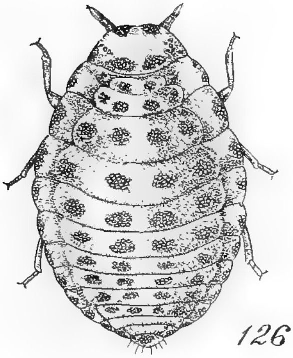
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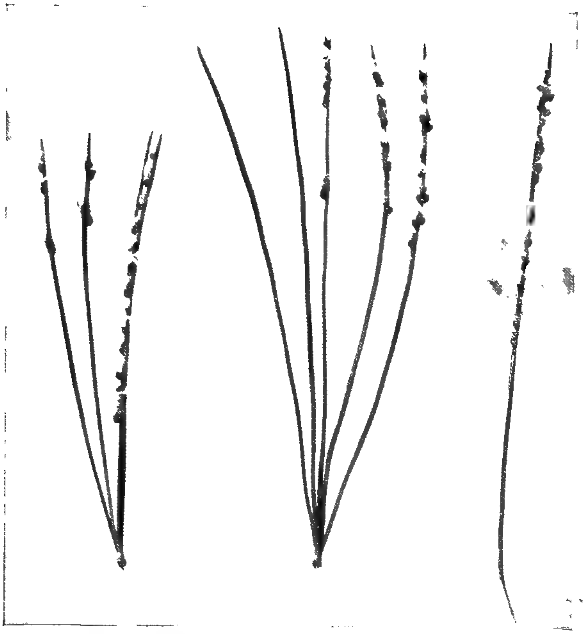
Fig. 127



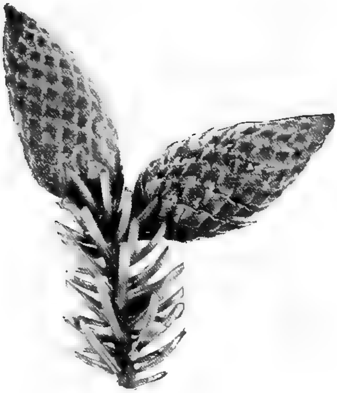
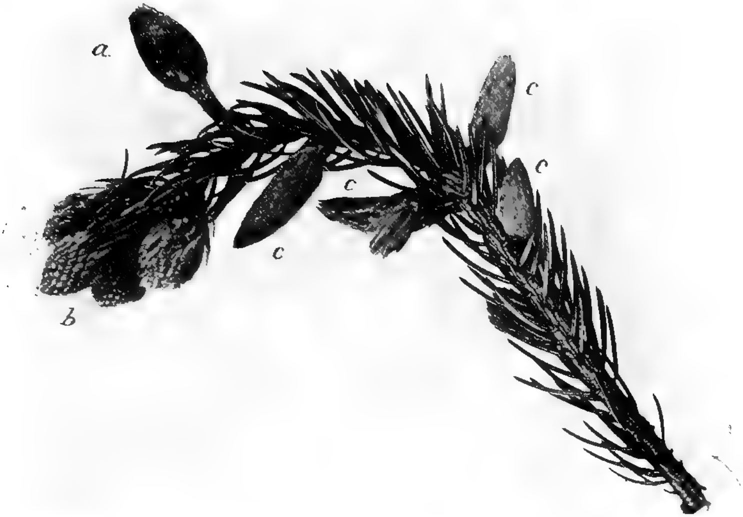
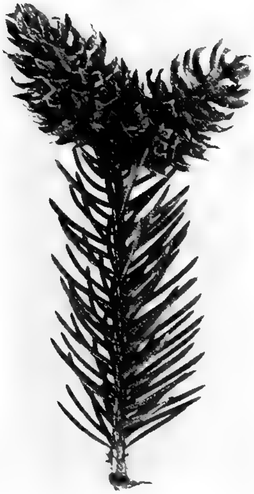


Fig. 128

Chermes pinifoliae Fitch. Fig. 127, Migrants on white pine. Fig. 128, Galls on black spruce.

Fig. 129





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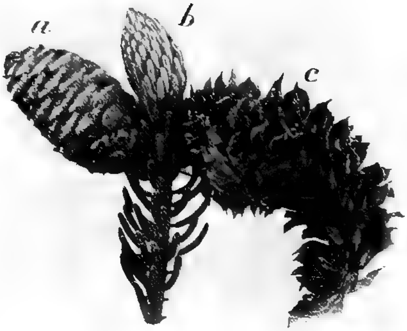


Fig. 130

Chermes pinifoliae Fitch. Galls on spruce.

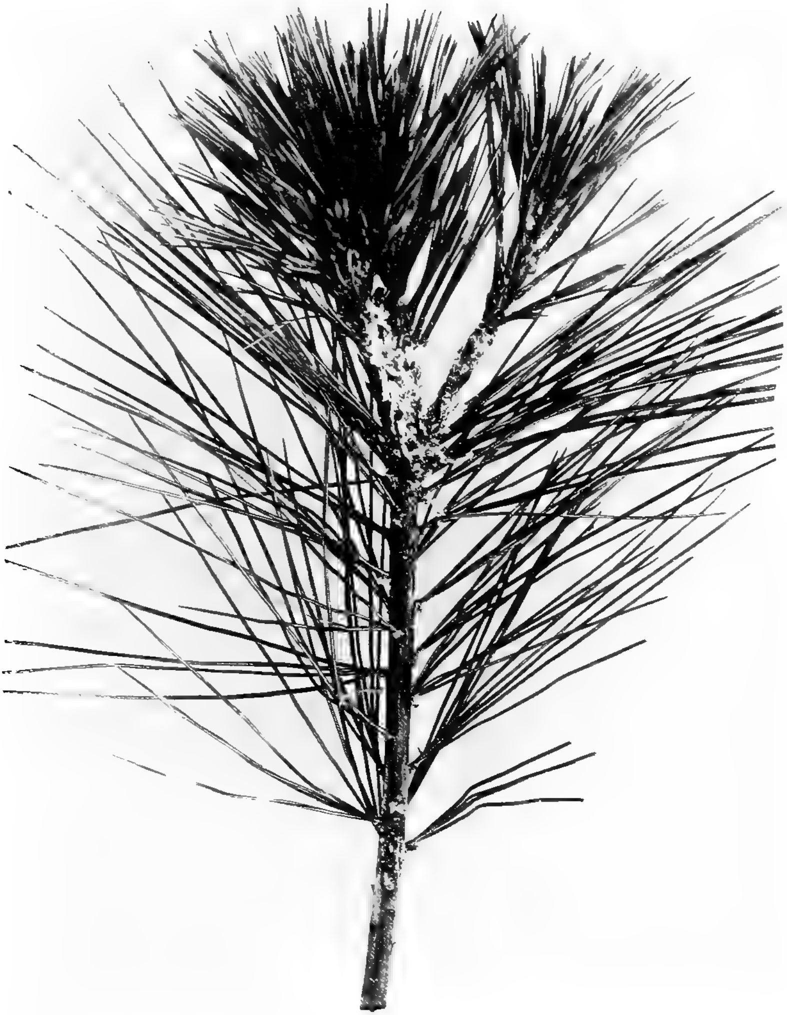
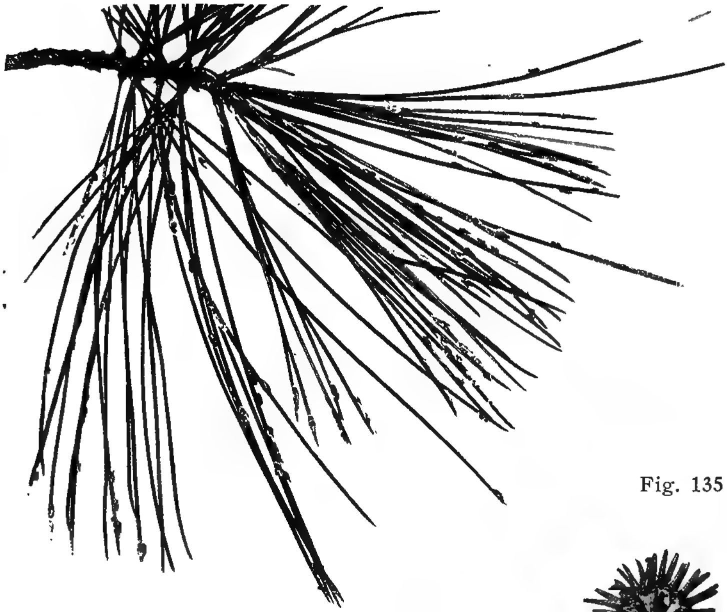


Fig. 132

Chermes pinifoliae Fitch. Young in white secretion towards tips of twigs of white pine

Fig. 133



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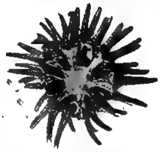
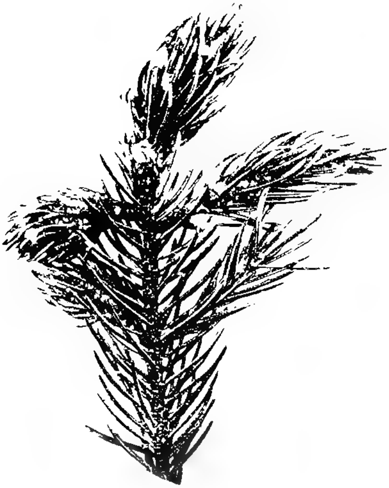




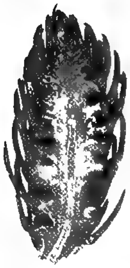


Fig. 134

Fig. 136

Chermes floccus Patch. Migrants on white pine and galls on spruce

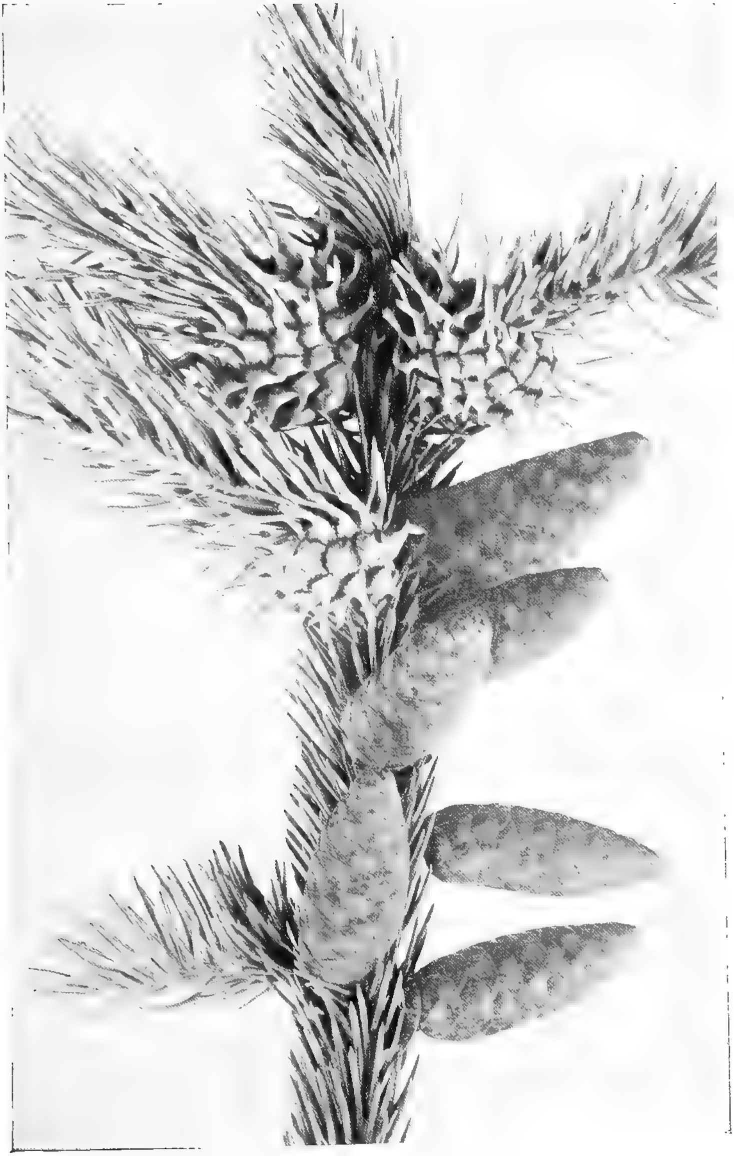


Fig. 137. *Chermes abietis* Linn. Galls on white spruce

Fig. 138

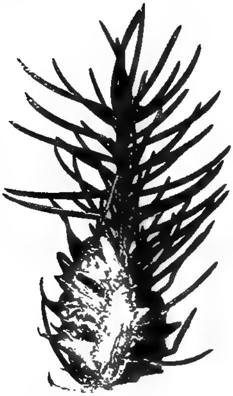
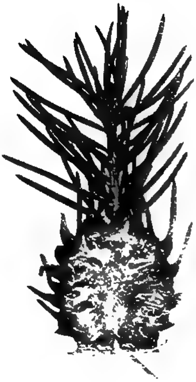


Fig. 139



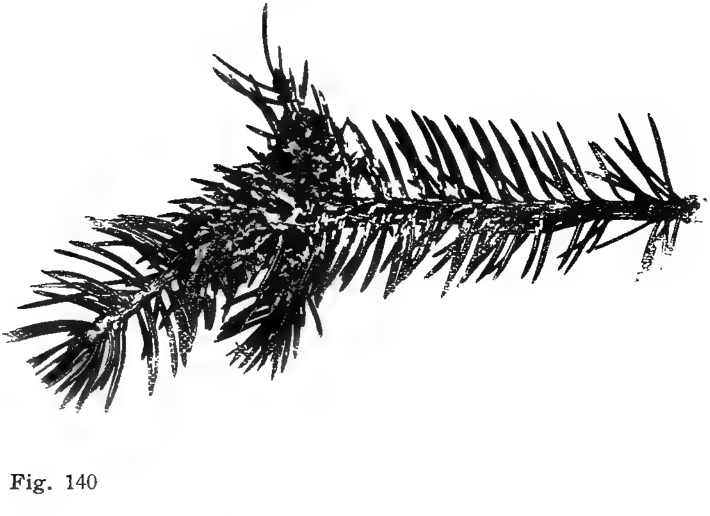


Fig. 140

Chermes abietis Linn. Galls on Norway spruce

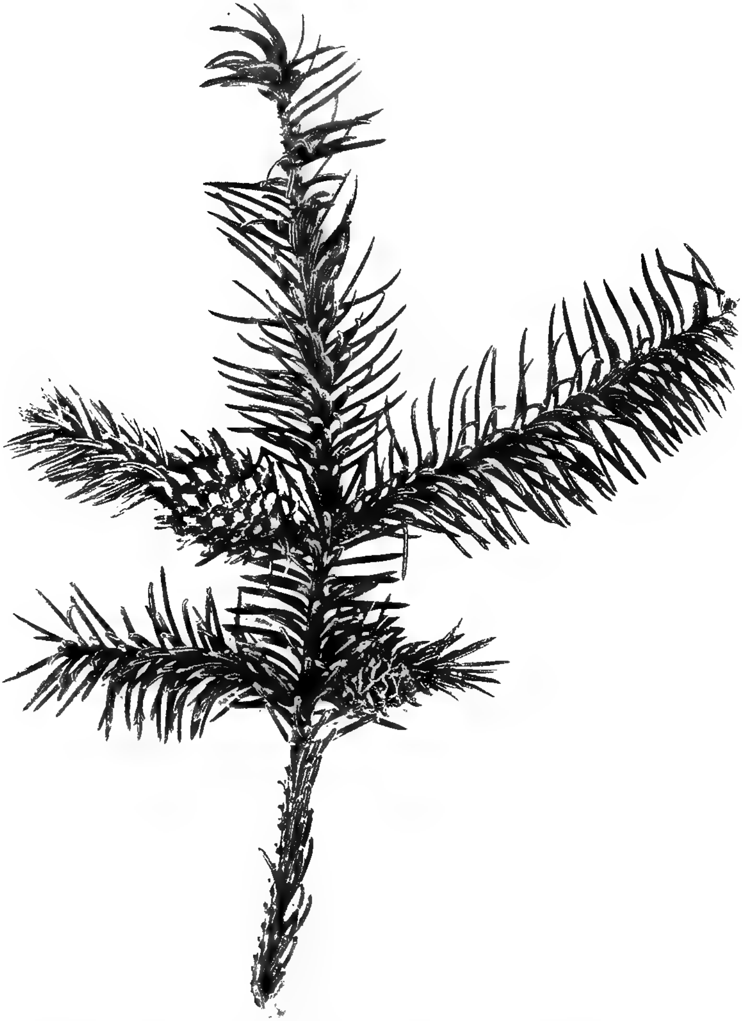


Fig. 141. *Chermes lariciatus* Patch. Galls on white spruce

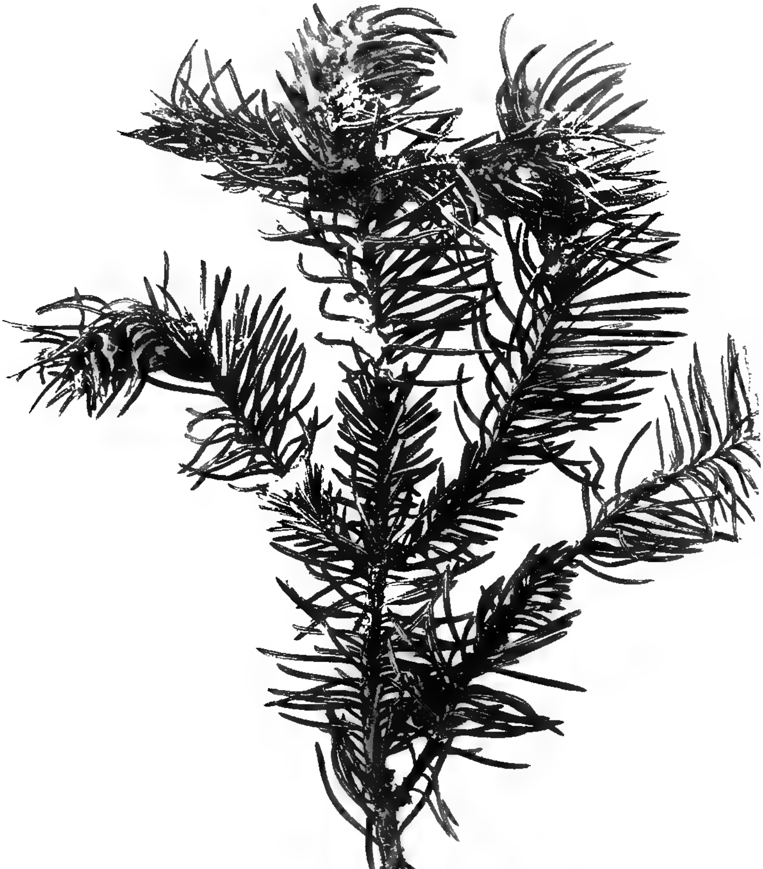
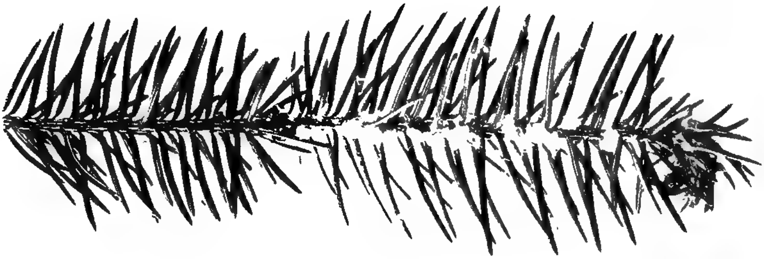


Fig. 142. *Chermes similis* Gillette. Galls on Norway spruce

Fig. 143



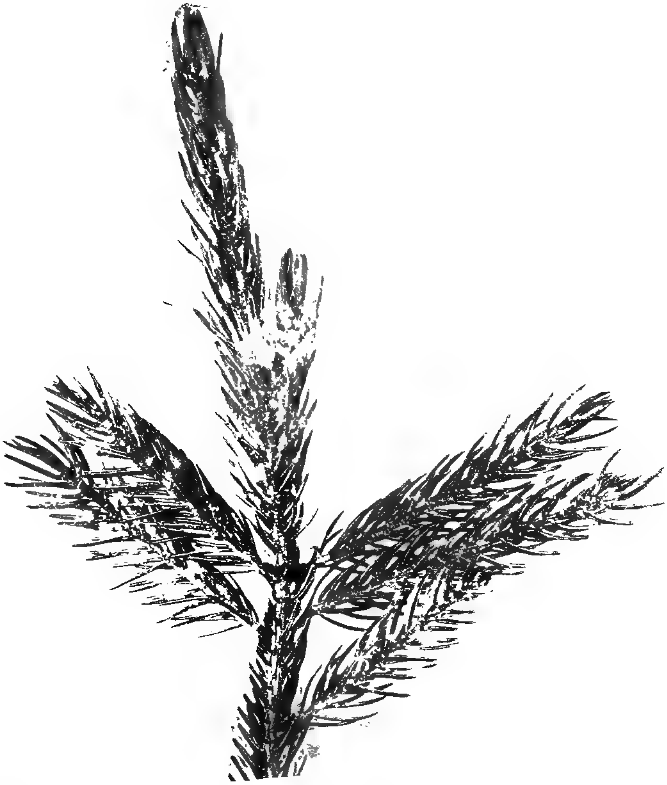


Fig. 144

Chermes similis Gillette

Fig. 145

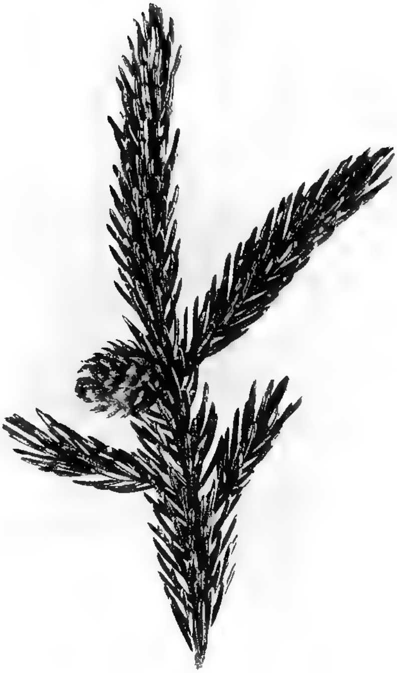
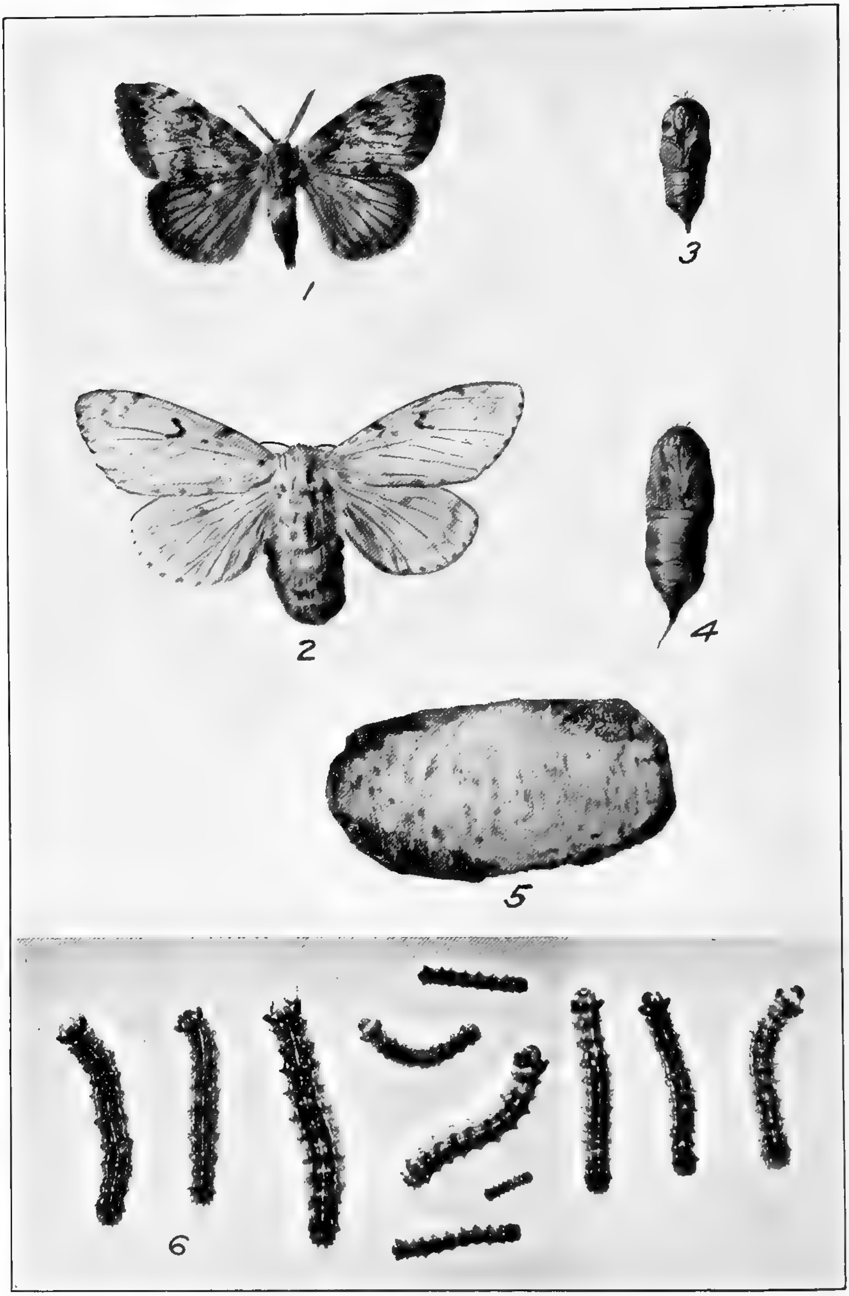


Fig 146

Fig. 145. *Chermes consolidatus* Patch. Gall on black spruce

Fig. 146. *Chermes pinicorticis* Fitch. On bark of white pine.

PLATE I.



THE GIPSY MOTH (PORTHETRIA DISPAR).

Fig. 1.—Male moth. Fig. 2.—Female moth. Fig. 3.—Male pupa. Fig. 4.—Female pupa. Fig. 5.—Egg cluster. Fig. 6.—Caterpillars; the largest are less than half grown. (Original.)

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 87.

L. O. HOWARD, Entomologist and Chief of Bureau.

REPORT ON THE FIELD WORK AGAINST THE GIPSY MOTH AND THE BROWN-TAIL MOTH.

BY

D. M. ROGERS,
Special Field Agent,

AND

A. F. BURGESS,
Expert in Charge of Breeding Experiments.

ISSUED AUGUST 13, 1910.

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1910.

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PREVENTING SPREAD OF MOTHS.

PARASITE LABORATORY.

W. F. FISKE, *in charge;* A. F. BURGESS, H. S. SMITH, W. R. THOMPSON, C. W. COLLINS, P. H. TIMBERLAKE, R. WOOLDRIDGE, *assistants.*

FIELD WORK.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., April 5, 1910.

Sir: The only accounts so far published by the Department of the large-scale work which is being carried on under congressional appropriations in the effort to limit the farther spread of the gipsy moth and the brown-tail moth in New England have been brief statements in the annual reports of the Chief of the Bureau of Entomology. The work has now reached such a stage that a comprehensive account of the work accomplished, the methods of work, and present conditions, is demanded. I therefore have the honor to submit for publication the accompanying manuscript, which includes a report on the field work for preventing the spread of the gipsy moth and the brown-tail moth, and which has been prepared by Messrs. D. M. Rogers and A. F. Burgess, of this Bureau. This report does not include a consideration of the efforts made to import and acclimatize the European and Japanese parasites of the gipsy moth and the brown-tail moth. That matter will be described in another bulletin. I recommend that the accompanying manuscript be published as Bulletin No. 87 of this Bureau.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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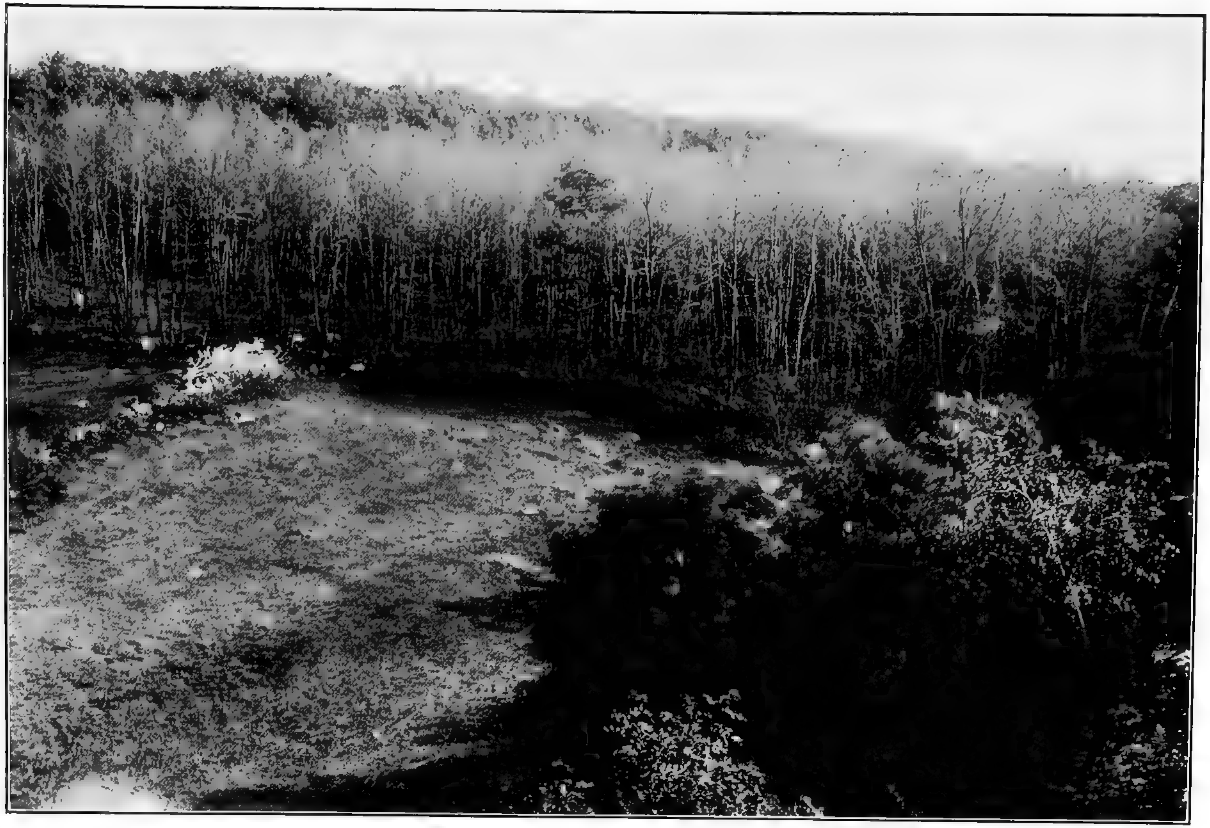


WOODLAND AREA IN MASSACHUSETTS DEFOLIATED BY THE GIPSY MOTH. (ORIGINAL.)

REPORT ON THE FIELD WORK AGAINST THE GIPSY MOTH AND THE BROWN-TAIL MOTH.

INTRODUCTION.

For nearly two decades eastern Massachusetts has suffered enormous loss to its forest, orchard, and shade trees, as well as to ornamental plantings which beautify many of the large country estates, by reason of the depredations of the gipsy moth (*Porthetria dispar* L.) (see Pl. II), and for the latter half of this period by the combined injury caused by this insect and the brown-tail moth (*Euproctis chrysorrhœa* L.). Both of these insects were introduced from Europe. During the past few years the situation became so serious, owing to the spread of these insects into Maine, New Hampshire, Rhode Island, and Connecticut, that appropriations from the National Government were urged by the States affected, and, owing to the great danger that these pests would become disseminated over the entire country, funds have been appropriated by Congress to assist in securing their control and of preventing further spread. The purpose of this report is to sketch briefly the life histories of the insects concerned, their habits since their introduction into this country, a statement of the injury caused by them here and in their native homes, and to discuss the methods used for their control, in order that this work may become better understood and the danger of the presence of the pests more thoroughly appreciated in sections which are not now infested. Free use has been made of the reports already published by the State of Massachusetts and other New England States, where warfare against these insects has been carried on in the past.

Acknowledgment and thanks are due to Dr. W. E. Britton, state entomologist of Connecticut, for the use of Plate III, figure 1, and to Prof. E. F. Hitchings, state entomologist of Maine, for the use of Plate VIII and text figure 16.

IMPORTANCE OF THE GIPSY MOTH AS AN INSECT PEST IN THIS COUNTRY.

During the summer of 1889 great injury was caused to the foliage of the street trees and of those on private estates in Medford, Mass., a city about 5 miles north of Boston, by caterpillars which appeared in enormous swarms. In many cases the trees were completely defoliated, and the insects crawled into the houses and upon the fences and walks, so as to become a public nuisance in the neighborhood. Specimens were sent to the office of the Massachusetts state board of agriculture at Boston, and were transmitted to Prof. C. H. Fernald, at Amherst, and, in his absence, were determined by Mrs. Fernald as the gipsy moth of Europe. An investigation in the neighborhood showed that this insect had been quite abundant and had caused considerable damage for a number of years, but, owing to the belief of most of the residents that it was one of the common native caterpillars, no action had been taken in the matter. As a result of persistent inquiry among the inhabitants of the infested section it was determined that some of these insects were introduced from Europe, probably in the egg stage, by Prof. Leopold Trouvelot, a French naturalist, about the year 1869. At that time this gentleman was conducting experiments with silkworms, and also with some of the American species of silk-spinning caterpillars. The evidence seems to show that some of the egg clusters, or young caterpillars, which he secured from Europe, escaped from his house where the experiments were being conducted, and, as he was aware of the dangerous nature of the insect in its native home, he destroyed all the caterpillars that could be found in the neighborhood and made public the fact that it had escaped. At that time the section in which he resided adjoined a large area of waste land, which was overgrown with sprouts and brush, and here the species became established. Its slow development as a serious pest was undoubtedly due to the fact that this area was burned over periodically by brush fires which destroyed large numbers of the insects, and also to the prevalence at that time of many insectivorous birds, which doubtless accomplished much in preventing the rapid increase of the species.

So thoroughly were the trees defoliated by the caterpillars that in many cases during the summer of 1889 and 1890 swarms of them practically covered the sides of many houses. Real estate in the neighborhood rapidly depreciated in value and many tenants moved to more congenial quarters of the city. The recorded statements of eye-witnesses of the conditions that prevailed seem almost incredible to one who has had no opportunity to observe the serious damage which this insect causes. Many trees and orchards died as the result of repeated defoliation, and during the winter of 1890, on petition of the city of Medford and the surrounding cities and towns, the matter was brought to the attention of the legislature, and the sum of $25,000 appropriated for abating the nuisance.

STATE WORK AGAINST THE GIPSY MOTH IN MASSACHUSETTS, 1890-1900.

The work against the gipsy moth was placed in charge of a paid commission of three men, appointed by the governor. At the time the work was begun it was thought that only a small area was infested, but on May 9, 1890, the commission reported to the governor that the infested area was "some sixteen times as large as at first represented,"and requested an additional appropriation of $25,000, which was granted.

Early in 1891 the commission was abolished by the governor and an unsalaried one appointed which carried on the work for a few months, until a law was enacted by the legislature giving the state board of agriculture authority to use "all reasonable measures to prevent the spreading and to secure the extermination of the *Ocneria dispar* or gypsy moth in this Commonwealth."

The board placed the work under the immediate direction of a committee, later known as the "Committee on gypsy moth, insects, and birds," which was made up of five of its members, who served without pay. Mr. E. H. Forbush, of Worcester, Mass., was appointed director of the field work, and Prof. C. H. Fernald, entomologist to the Massachusetts agricultural experiment station at Amherst, was given supervision of the experimental and scientific work, and energetic measures were at once begun to exterminate the pest, and were continued until February 1, 1900.

RECORD OF THE GIPSY MOTH IN ITS NATIVE HOME.

A perusal of the European literature concerning this insect, which was thoroughly examined and the results presented in the report on the gipsy moth by Forbush and Fernald, published by the Massachusetts board of agriculture in 1896, indicates that it was a pest in nearly all European countries at the time the first entomological writings were published, and there is good reason to suppose that even before that time much serious devastation to trees and forests resulted from it, although it was probably referred to as "the plague," and was believed by the inhabitants to be a scourge sent by the Almighty as a penalty for their wrongdoings. Many cases are on record where this insect became abundant and defoliated thousands of acres of forests, as well as the fruit and shade trees and shrubs in the populated regions. The literature indicates that this moth is abundant periodically and causes enormous loss throughout continental Europe, western Asia, and Northern Africa. It has been found as far north as Stockholm and is known to occur in Algeria. Slight, though not serious, infestations have been reported in England, and this or a closely allied species occurs in Japan, and is said to be present in sections of China. During the year 1909, Prof.

Trevor Kincaid, who was engaged by the Bureau of Entomology, in cooperation with the State of Massachusetts, for the purpose of collecting parasites of this insect in Russia, found during his explorations that thousands of acres of forests were completely denuded, and in other localities trees were dying over large areas as a result of previous defoliations. Dr. L. O. Howard, Chief of the Bureau of Entomology, while visiting, in 1909, the corps of European agents engaged in collecting parasites of the gipsy moth in Europe, found a large forest area near Nantes, France, which was completely stripped by this pest. In fact, the whole European history of this moth is a continuous record of periodical outbreaks of greater or less severity, which have caused enormous damage to trees from the time of the earliest writings on entomology down to the present time. The situation in Japan is not as serious as in Europe, owing to the efficient work of certain parasites which tend to keep the insect under control.

LIFE HISTORY OF THE GIPSY MOTH.

THE EGGS.

(Pl. I, fig. 5.)

The female gipsy moth deposits her eggs in clusters containing normally from 400 to 500 eggs, which are covered with hair from her body; this protects them from the action of the elements and renders their destruction, even by fire, quite difficult. The clusters are fully 1 inch in length and about half as wide, and have the general appearance and color of a small piece of sponge. The number of eggs varies considerably and depends largely on the food supply and the vigor of the caterpillar from which the female develops. In colonies where the food supply has been practically exhausted by the larvæ, egg clusters are often found containing not more than 50 or 75 eggs, while, on the other hand, a number of cases are on record where single clusters contained over 1,000 eggs. The majority of the eggs are deposited about the middle of July, although there is considerable seasonal and individual variation. Females have been found depositing egg clusters as early as June 25 and as late as October 7. Crevices in the bark, holes in trees, stone walls (Pl. III, fig. 2), or rubbish piles are favorite places for the deposition of eggs, as they afford shelter for the full-grown caterpillar about to pupate and protect the pupa and the newly emerged moth. Many clusters are deposited under steps or porches of houses, in outbuildings near infested trees, as well as on the trunks (Pl. III, fig. 1) and on the under side of the branches of the trees themselves. Hatching takes place early in the spring, about the time the trees are coming into leaf. A few cases are on record where the caterpillars hatched in the fall, but this is unusual.

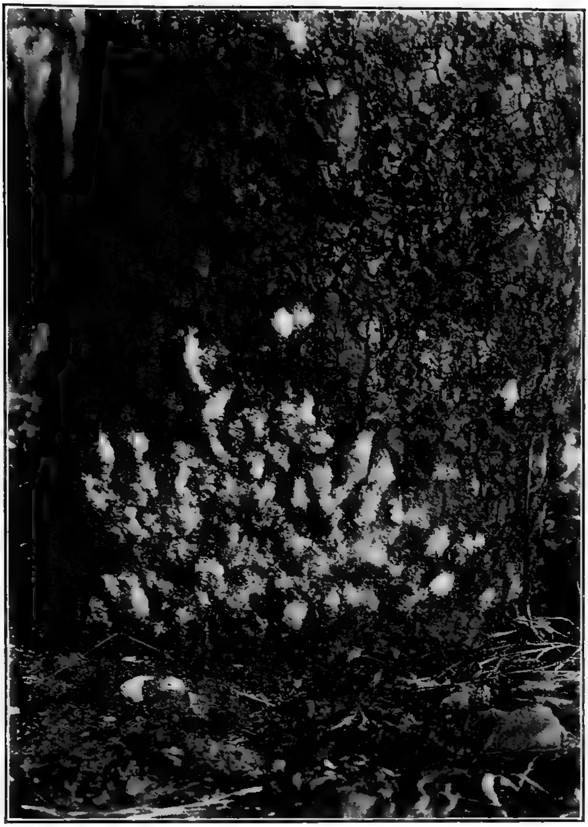


FIG. 1.—EGG CLUSTERS OF THE GIPSY MOTH ON TRUNK OF APPLE TREE, WALLINGFORD, CONN., DECEMBER, 1909. (FROM BRITTON.)

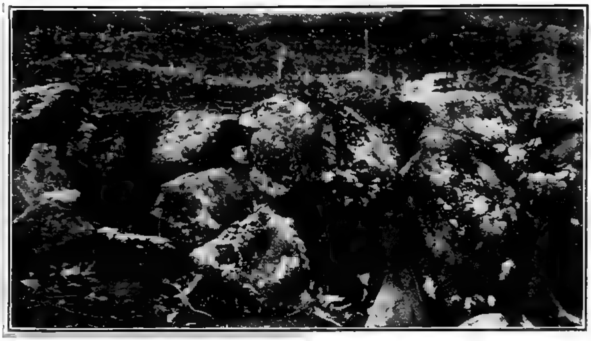


FIG. 2.—EGG CLUSTERS OF THE GIPSY MOTH ON STONE WALL. (ORIGINAL.)

[This wall has been overturned to expose the egg clusters.]

THE LARVÆ.

(Pl. I, fig. 6.)

The newly hatched caterpillars feed upon the small leaves, making "pin holes" in them. As a rule the caterpillars molt five times, but quite a number of cases are on record where an additional molt took place before they entered the pupal stage. The newly hatched caterpillars are about one-eighth of an inch in length and covered with long, slender hairs. During warm weather they feed upon the leaves, but when the temperature is low, or during rainy or unsettled weather, such as is common in early spring, they congregate in masses in the crevices of the bark or on the egg clusters from which they hatched. As the weather becomes warmer in the early summer, they grow rapidly and devour the entire leaves except the woody veins. Until they are about half grown, the caterpillars are able to suspend themselves from the twigs or branches of the trees by means of silken threads spun from their bodies, and in this way they often drop upon animals, carriages, or other moving objects, and may be conveyed to localities where none of the species exists. After the caterpillars have molted the fourth time, which usually occurs about the middle of June, a considerable change in coloration appears. On the dorsum of each of the first five segments behind the head is a pair of prominent blue tubercles, while on the following six segments the tubercles are of a dark-red color. The arrangement and coloration of these tubercles is characteristic of the species. The feeding habits change somewhat with the progress in growth of the caterpillars, for after becoming half grown the caterpillars seem to prefer shelter from the sun and feed for the most part at night or during cloudy weather. During the warm part of the day they remain concealed in crevices in the bark, crawl to the ground, or seek any convenient shelter from the sun. This habit serves as a protection against their natural enemies, and although in moderately infested sections it is usually possible to find caterpillars feeding at midday during sunny weather, still the majority are either in hiding or are feeding in such situations as to be largely protected from direct sunlight. The period spent in the caterpillar stage extends, on the average, from early in May to July 5, or is approximately seven weeks. Egg clusters deposited in cool situations do not hatch as readily as those more favorably located; hence the entire length of the feeding period varies considerably. Larvæ have been found as early as the 1st of April and as late as September 6. In certain areas along the seacoast and on islands which are surrounded by tidewater, the hatching of the eggs is retarded, and pupation takes place much later than where conditions are normal. The full-grown caterpillars measure about 2 inches in length, although there is considerable variation in this respect, due largely to the amount of food available. It is a noticeable fact that in bad colonies, where most of the foliage has been eaten, the caterpillars pupate early in the season before attaining normal size.

This insect has a varied list of food plants; in fact, it will eat almost any kind of vegetation, although it seems to prefer the foliage of oaks (fig. 1), willows, and apple trees. Repeated observations have shown that the ash (fig. 1), juniper, and red cedar are practically immune from attack, while the maple is not injured to any great extent if more desirable food is within easy reach. Grass and garden crops are sometimes seriously injured when the supply of other food has been exhausted.

A few years ago a farmer in Lynn, Mass., stated that with the assistance of his men he collected several bushels of the caterpillars that were feeding in his field of sweet corn. The caterpillars had stripped the trees in a piece of woodland near by, and, after eating all the foliage from the bushes and low growth, had migrated in countless numbers across the road and attacked the growing corn.

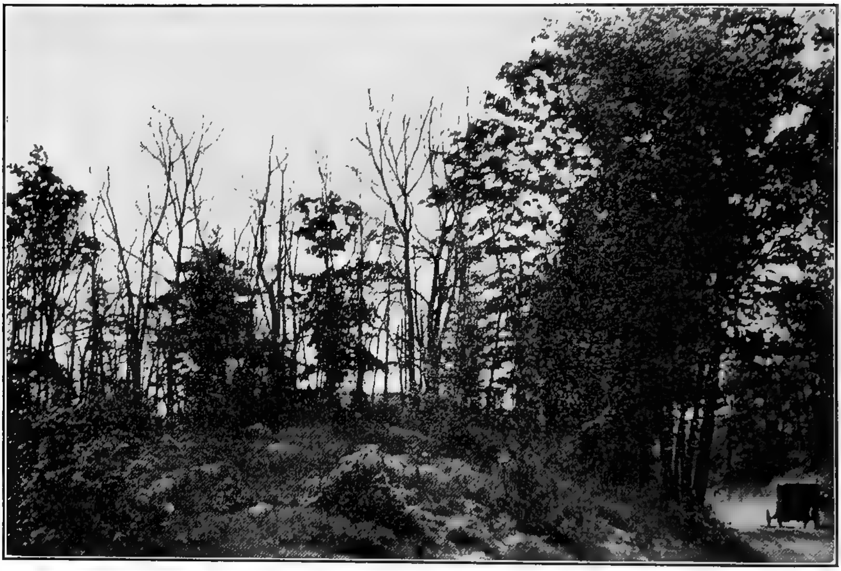


FIG. 1.—Roadside view in Massachusetts, showing oak and ash trees, the former killed by the gipsy moth (*Porthetria dispar*) and the latter practically uninjured. (Original.)

Most of our native leaf-eating insects confine their diet to a small number of food plants, and it is unusual for a species to feed on both deciduous and coniferous trees. The gipsy-moth larvæ, after becoming half grown, feed with avidity on conifers, especially the white pine, and many acres of this, as well as other coniferous trees, have been defoliated and killed in the infested region of New England (fig. 2).

The white pine, as well as the spruce and the hemlock, is unable to survive after one complete defoliation, and when only partially denuded the trees are usually attacked by bark borers and other insects so that death soon follows. The proper treatment of conifers to prevent injury by the gipsy moth will be described farther on in this report.

THE PUPÆ.

(Pl. I, figs. 3, 4.)

After the caterpillars have finished feeding they usually select more or less protected places in which to pupate. Stone walls, rubbish piles, and open spaces beneath porches or outbuildings furnish excellent places for caterpillars to enter the pupal stage. Of course, a large number remain on the trees, where they usually pupate on the under side of the branches, beneath loose bark, or in holes and cavities, or descend to the base of the trees before transforming. Previous to pupation the caterpillar spins a few threads of silk in order to attach itself firmly. The body then shortens considerably and pupation is accomplished by the integument of the segments behind the head splitting dorsally and the whole larval skin is forced back to the end of the body, the pupa remaining beneath the network of silk which held the caterpillar in place. The pupa is dark reddish-brown, and the body segments bear yellow hairs, which are arranged in groups. From 7 to 17 days are spent in this stage before the moth emerges. As a rule female pupæ are much larger than those of males, but the sex can always be determined by the structure of the last segment of the abdomen.

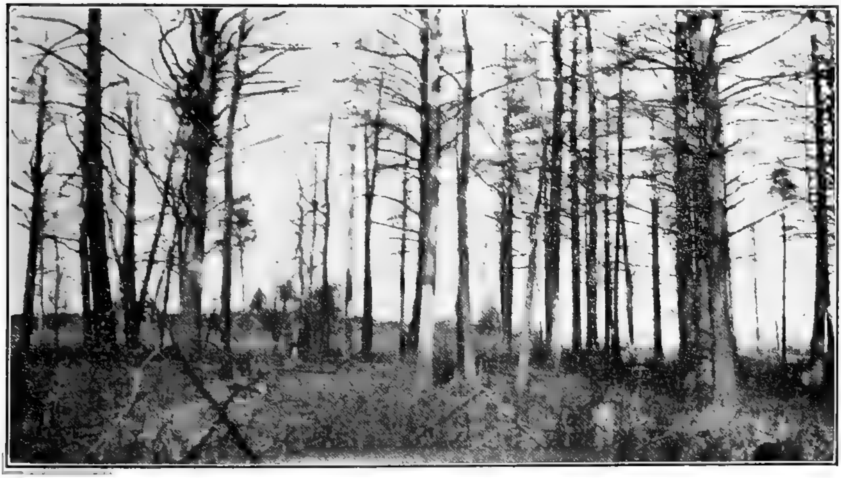


FIG. 2.—Pine trees killed by the gipsy moth. (Original).

THE ADULTS.

(Pl. I, figs. 1, 2.)

The male moths ordinarily emerge from the pupæ earlier than do the females. The body of the male is light brown and the wings are considerably darker and have prominent black markings. Male moths are able to fly considerable distances and are especially active during warm sunny weather. The zigzag motion of the flight of these moths is characteristic of the species. The body of the female is light buff. The abdomen, which is very large and almost completely filled with eggs, is densely covered with short yellow hairs which are used by the moth to protect the eggs as they are deposited in the cluster. The wings are white, with prominent black markings, and, although they are apparently of ample size, the female moth is not able to fly on account of the weight of the body. The adult insects take no food, and after mating, which takes place soon after emergence from the pupa, the female begins depositing eggs. As a rule the egg cluster will be found near the pupal case from which the female emerged, but occasionally the moth will crawl a considerable distance, especially if disturbed. When a search for egg clusters is being made the discovery of a female pupal case is indication that an egg cluster is present near by. Sometimes moths which emerge from pupæ that are attached to the branches of trees fall to the ground and deposit their eggs on the trunks of surrounding trees or on leaves or rubbish. By the time the egg cluster is completed, the abdomen has shrunken greatly and in a few hours the moth dies.

METHODS EMPLOYED IN WORK AGAINST THE GIPSY MOTH.

SCOUTING.

As the law enacted by the Massachusetts legislature in 1891 required the state board of agriculture "to prevent the spread and secure the extermination" of this insect, a determined effort was made to ascertain the extent of the area infested. Men were trained so that they were able to recognize the moth in all its stages, and as soon as they had secured sufficient experience the most expert ones were sent into the territory not known to be infested to make a thorough inspection. As a result of this work, it was found that, while the area supposed to be infested in 1890 covered 9 cities and towns in whole or in part and embraced about 50 square miles, the pest had become established in more or less numbers in 30 cities and towns, covering an area of 200 square miles. This spread had undoubtedly been going on for a number of years, and as the thickly settled sections became badly infested the small caterpillars were easily conveyed long distances owing to their habit of spinning down from trees onto vehicles or other moving bodies. Many colonies were discovered on the premises of milkmen and market gardeners who made regular trips to the infested section to distribute their products.

SPRAYING.

It was at first believed that this insect could be successfully controlled, like most other leaf-eating species, by spraying the trees with Paris green, a remedy which was then in common use. Experiments, however, showed that it was impossible to kill the caterpillars with this spray after they became half grown, unless it was used so strong that it resulted in severe injury to the foliage of the trees. Mr. F. C. Moulton, who conducted an extensive investigation with insecticides in the years 1891 and 1892, was able to prepare a new insecticide, arsenate of lead, which could be used in sufficient strength to kill the caterpillars without injuring the foliage. This work was later taken up by Messrs. A. H. Kirkland, F. J. Smith, and A. F. Burgess, under the direction of Prof. C. H. Fernald. A large number of experiments were made, using different formulas, which demonstrated the practical effectiveness of this poison and the proper method of its preparation. The poison as used at that time was made by dissolving the proper amounts of arsenate of soda and acetate of lead salts in separate vessels containing water. These solutions were then brought together and a precipitate, consisting of arsenate of lead, was formed. Usually the fresh precipitate was prepared in the field. In recent years, since this poison has come into general use throughout the country for treating trees infested with leaf-eating insects, it is made by manufacturers in a similar way, and is put on the market in the form of a paste which mixes readily with water, thus preventing the delay occasioned by mixing the raw chemicals and obviating the danger of securing impure materials, which might cause injury to the foliage or crop treated.

Some improvements were made in spraying machinery, which was very crude when we consider the equipment used at the present time. Spraying with the facilities then at hand was a very expensive operation, and in many cases gave unsatisfactory results, especially when large trees were treated. Owing to these facts, and because every effort was being made to secure the extermination of the insect, spraying was undertaken only in a limited way.

BURLAPPING.

The secretive habits of the caterpillars suggested the provision of artificial hiding places, and for this purpose burlap bands were placed about the trunks of the trees. Bolts of burlap were cut into strips about 8 inches wide, which were rolled for the convenience of the workmen. A band was placed around each tree about as high as a man's shoulder and fastened in the center with twine, the upper part being folded down, forming an excellent shelter for the caterpillars. By examining the burlaps frequently and crushing the larvæ underneath great progress was made in destroying the pest. The free edges of the burlap should be kept loose from the trees so that the larvæ can easily crawl under the folds. This method can not be used advantageously until the caterpillars are about half grown, as they do not often seek shelter until that time. The expense entailed is considerable, but it is one of the most effective measures where extermination of the insect is desired.

STICKY BANDS.

Numerous attempts were made to use a sticky material. such as printer's ink, tar, or other substances, applying them to bands of tarred paper on the trunks of trees to prevent the caterpillars from ascending. Several tons of a German product, known as "raupenleim," were tried but none of these preparations proved satisfactory for wholesale use. Success in using such bands was not attained until the material known as tanglefoot came into use, about five years ago.

CUTTING AND BURNING.

In order to prepare infested territory so that it could be treated effectively and economically, it was necessary to cut out and burn the brush and sprout growth, as well as trees that were hollow and partially decayed. This method reduced to a minimum the number of trees to be burlapped or otherwise treated, and by removing the low growth the larvæ were forced to feed on the trees where they could be more easily destroyed.

A method employed against the young caterpillars hatched from egg clusters located in stone walls or rocky areas was to clean out all brush and undergrowth during the winter. As soon as the larvæ appeared in the spring the ground and walls were burned over by using a device known as a cyclone burner. This consisted of a 15-gallon oil tank, on which was mounted a small force pump. The oil was conducted through a hose to an iron extension rod, at the end of which a nozzle of the Vermorel type was fitted. The fine mist of oil forced from the nozzle was ignited and the ground and walls burned over. To secure best results a large ball of flame should be maintained which can be forced into the cracks or cavities in walls or ledges in order to destroy the larvæ. Paraffin gas oil or a light grade of crude petroleum can be used. Two men are required to operate this outfit satisfactorily. The action of the oil soon destroys the hose, so that it seldom lasts more than one season.

PRUNING.

As the female moths deposit their egg clusters under loose bark and in holes and cavities in the trees, and also because the larvæ seek such hiding places, it became necessary to rid the trees of these natural shelters. To accomplish this purpose a considerable amount of pruning and filling of cavities was required. This work had to be skillfully done, especially when fruit or shade trees in cities or towns were treated. Many ingenious methods were devised for carrying on these operations, some of which have been adopted by professional foresters and others who have taken up the business of caring for trees.

TREATING EGG CLUSTERS.

The insect exists in the egg stage nearly nine months in the year and many experiments were tried to determine the most effective method of treating egg clusters. The first method used was that followed in Europe and consisted simply in scraping off the egg masses and burning them. In removing the eggs many were scattered, even if the work was carefully done, and as such eggs hatched in due time it became necessary to secure a better method of treatment. It was found that they could be killed by saturating the clusters with crude coal-tar creosote to which was added a small amount of either coal tar or lampblack to discolor them and enable the workmen to tell instantly the ones that had been treated. (See fig. 3.)

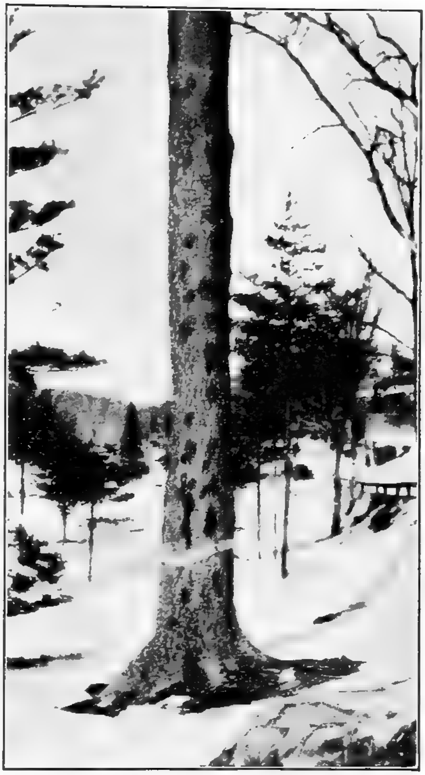


FIG. 3.—Trunk of pine tree, showing tanglefoot band and egg clusters that have been treated with creosote. (Original.)

It was necessary to make a very thorough search of all objects likely to harbor egg clusters if satisfactory results were expected, and this required much climbing of high trees as well as careful ground work. The pupæ and moths were crushed or treated with creosote when found by the workmen.

It was necessary to apply a combination of methods to secure satisfactory results and many localities had to receive special treatment on account of their location and condition of infestation. Methods which could be readily applied in wooded areas were entirely unsuited for use in residential sections.

DISCOVERY OF THE BROWN-TAIL MOTH IN AMERICA.

The work on the gipsy moth resulted in a great reduction of the numbers of the insect and a steady improvement in the condition of the infested territory, in spite of the fact that the legislature seldom granted the appropriations which were deemed absolutely necessary by the board of agriculture, and the availability of the funds was often delayed so that many of the trained men were thrown out of employment for a part of the year, which of course greatly affected the efficiency of the force. To add to the difficulties of the situation complaints were received during the summer of 1897 that trees and shrubs in Somerville, Mass., were being severely injured by an insect which appeared to be new to the region.

An investigation showed that the trouble was caused by the brown-tail moth (*Euproctis chrysorrhœa* L.), an insect well known and at times as noxious in Europe as the gipsy moth.

Careful inquiry indicated that this species was probably imported from Europe a few years before on rose or nursery stock by a local florist. The attention of the governor was called to the matter by the state board of agriculture, and, realizing the seriousness of the pest and the desirability of stamping it out at once, he sent a special message to the legislature, which was then in session, suggesting that action be taken without delay.

A law was passed requiring property owners to destroy the insects on their premises, and the opportunity for stamping out the pest before it could become generally disseminated was lost. As is always the case, some of the citizens and municipalities made every effort to destroy the pest, but through the neglect and indifference of others little permanent good was accomplished.

The following year $10,000 was diverted from the gipsy moth appropriation to "prevent the spread of the brown-tail moth," but the money did not become available for use until after the caterpillars had left their winter webs and begun feeding. Thus the insect was allowed to spread for two seasons after it was discovered, because the work was not taken up promptly under proper supervision. When work was begun it was found that the insect had spread over a large territory and it seemed almost impossible to stamp it out. A detailed account of this insect was prepared by Fernald and Kirkland in 1903 and published by the Massachusetts board of agriculture.

EUROPEAN HISTORY OF THE BROWN-TAIL MOTH.

The brown-tail moth is one of the oldest known pests in Europe and is called in many of the earlier writings "la commune," or the communistic one. It is said to be distributed over central and southern Europe and to extend to Algiers on the south and the Himalayas on the east. It has been found in limited numbers in England and may be present in Japan, although the record from the latter country is somewhat doubtful. Few, if any, species have caused more havoc to foliage than has this one, and many accounts of its destructive work have been recorded. Deciduous forest and fruit trees are often denuded, and even garden crops sometimes suffer from the enormous numbers of the caterpillars. Similar conditions now prevail in some sections of Europe, for during the spring of 1909 thousands of seedling trees, badly infested with the webs of this insect, were shipped to this country from nurseries in France.

Mr. H. L. Frost, of Arlington, Mass., informed the writers that while in Germany during the summer of 1909 he found that the Thiergarten in Berlin, a large park, had been closed to the public owing to the large numbers of larvæ of the insect which were defoliating the trees. The action of the officials in closing this park was in part due to the serious poisoning of people as a result of coming in contact with caterpillars while visiting the grounds.

Dr. L. O. Howard, Chief of the Bureau of Entomology of this Department, states that he observed this insect present in injurious numbers in certain sections of Europe, particularly in France, during the summer of 1909.

LIFE HISTORY OF THE BROWN-TAIL MOTH.

THE EGGS.

(Pl. IV, fig. 4.)

The female brown-tail moth deposits her eggs in a single elongated cluster on the underside of a leaf, usually near the end of a twig, covering it with brown hair from the end of her body. Each cluster is about two-thirds of an inch long and contains from 200 to 400 eggs which are nearly globular, and yellow. The eggs are deposited during the first three weeks in July, and hatching takes place in from 15 to 20 days.

THE LARVÆ.

(Pl. IV, fig. 5.)

After hatching the young larvæ begin feeding on the epidermis of the leaf on which the egg cluster was deposited and later attack others near by. They are gregarious and usually feed on the terminal leaves of the twigs, which are drawn together and held in position by silk spun by the caterpillars. As the season advances more leaves are drawn into the web, and this is lined with silk and serves during the winter as a hibernaculum for the larvæ. The caterpillars do not remain in a single large cell. The web is divided by cross partitions into small pockets in each of which one or more of the larvæ remain during the winter. The webs (fig. 4) are very conspicuous on the trees during the winter, as they are usually located at the tips of the branches. (See fig. 5.) During the first warm days of spring the caterpillars come forth from the webs and begin feeding on the bursting buds. In cases where the trees are badly infested the tiny leaves are devoured as fast as they develop. The caterpillars feed until about the 20th of June before becoming full grown. They molt four or five times in the spring, and when ready to spin their cocoons are about an inch and a half in length. The body is nearly black and covered with rows of yellow spines and barbed hairs which arise in tufts on the back and sides. There is also a row of nearly white tufts on the full-grown larvæ, which arise along each side of the dorsal abdominal segments. The next to the last two segments each bear a small coral-red tubercle on the dorsal part. As soon as the caterpillars are full-fed they seek shelter and spin up loose cocoons, within which they pupate.

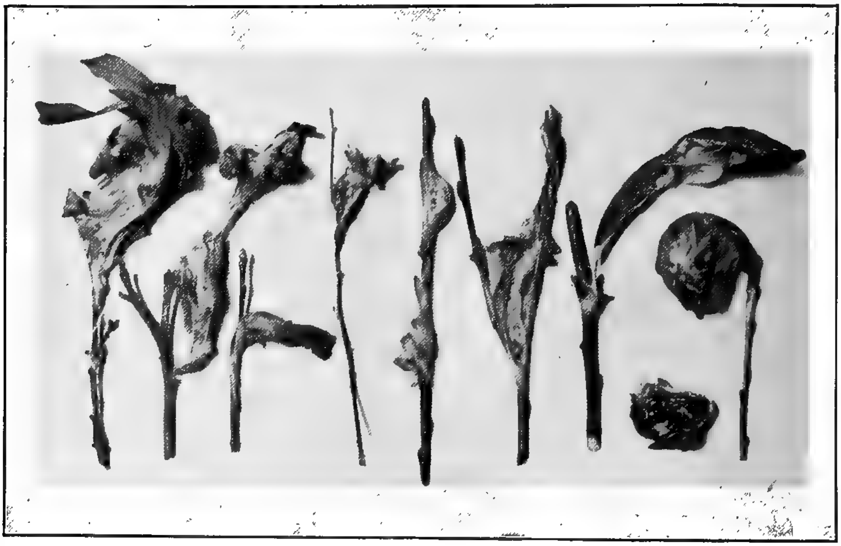
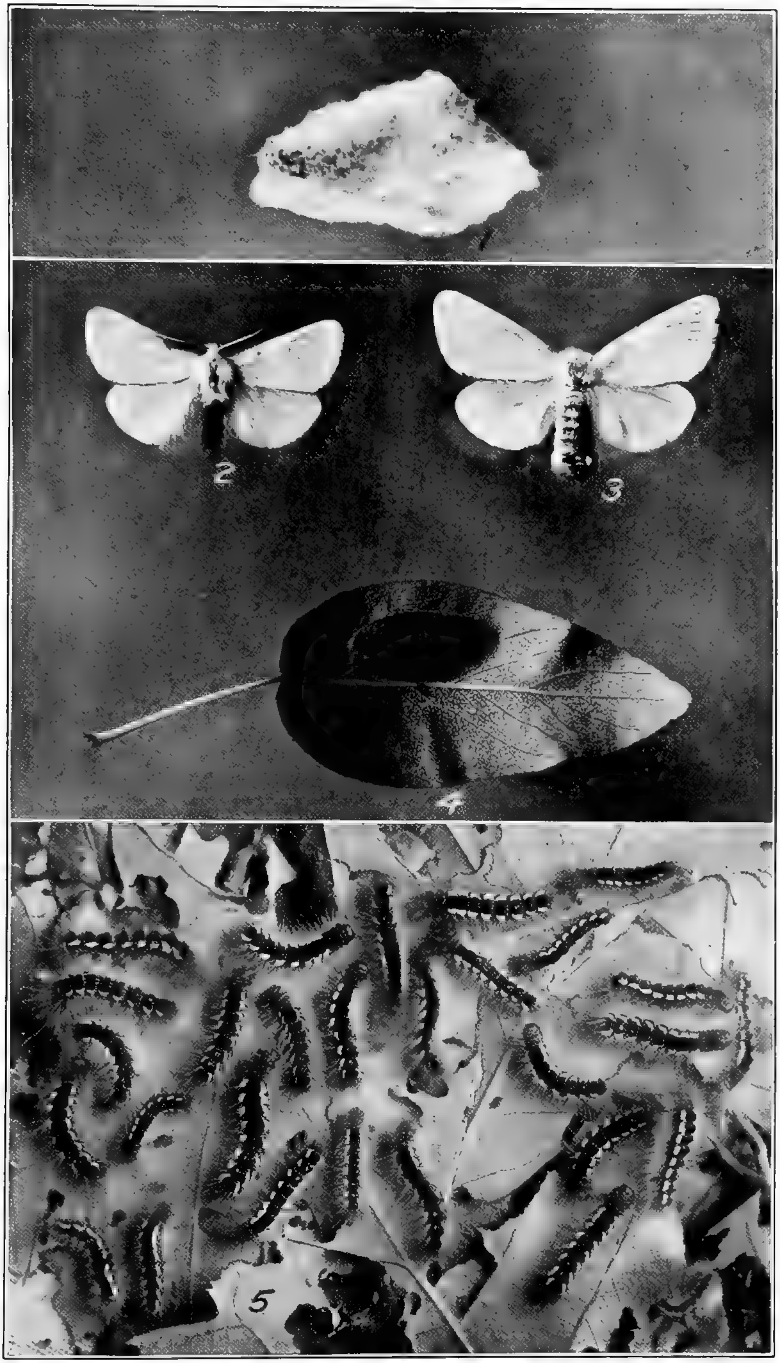


FIG. 4.—Winter webs of the brown-tail moth (*Euproctis chrysorrhœa*). (Original.)

THE PUPÆ.

The cocoons (Pl. IV, fig. 1) may often be found in leaves which have been webbed together by the larvæ, in crevices in the bark,



THE BROWN-TAIL MOTH (EUPROCTIS CHRYSORRHŒA).

Fig. 1.—Cocoon. Fig. 2.—Male moth. Fig. 3.—Female moth. Fig. 4.—Egg cluster on leaf. Fig. 5.—Caterpillars on leaf. (Original.)

under burlaps, beneath the clapboards or under the eaves of houses, or in any situation which affords reasonable shelter. As a rule the cocoons will be found in masses, and, as the silk with which they are constructed is interwoven with hairs from the bodies of the caterpillars, severe poisoning may result in removing them from their resting places. The pupal stage lasts about 20 days, most of the moths emerging during the first 10 days in July. Weather conditions during the spring serve to accelerate or retard the growth of the caterpillars, so that the time of pupation and emergence of the moths varies considerably.

THE ADULTS.

(Pl. IV, figs. 2, 3.)

Both males and females are white and bear a tuft of yellowish-brown hairs at the end of the abdomen, from which the name "brown-tail moth" is derived. Although the abdomen of the female is much larger than that of the male, the female of the brown-tail moth, unlike that of the gipsy moth, is capable of strong flight, and the spread of the species is therefore not handicapped as in the case of the latter species. Both sexes fly more frequently at night than in the daytime, although most of the eggs are deposited during the day. The moths are attracted to strong light, especially electric arc lights in cities and towns, and during the nights when the moths are most abundant the areas around these lights sometimes have the general appearance of a heavy snowfall, due to the great number of flying insects. Stores and houses in the neighborhood are often invaded by the moths, and several cases are on record where merchants have been obliged to close their stores during the height of a moth flight in order to prevent annoyance and trouble caused by the enormous num-

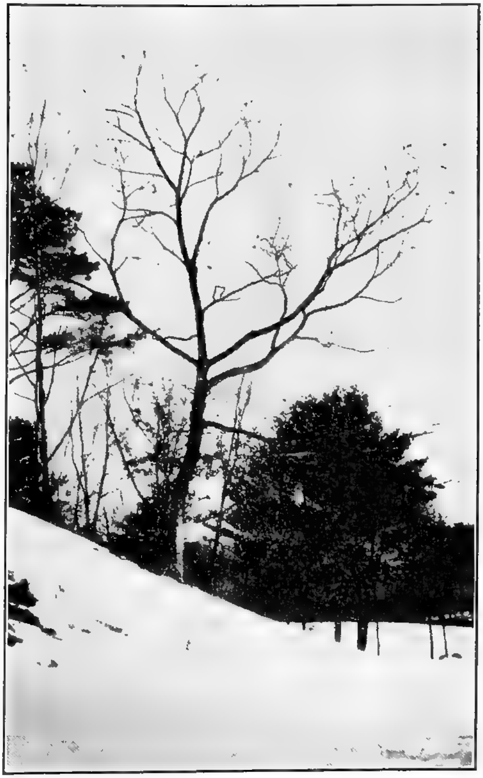


FIG. 5.—Oak tree in winter, showing webs of the brown-tail moth at tips of branches. (Original.)

bers of these insects. The morning following a flight, the houses, telephone poles, and trees in the immediate vicinity of the arc lights are usually well covered with small white moths (see fig. 6); and it is no uncommon thing for lamp trimmers to collect one or two quarts of dead moths inside the globe surrounding a light. The hairs from the abdomens of the moths are poisonous, as well as those from the caterpillars, and a great many persons have been caused severe inconvenience by coming in contact with the adult insects.

The moths' habit of flying to lights serves to increase their distribution, especially in the more thickly populated regions.

Large numbers of the insects are killed, however, by coming in contact with the light and many of the survivors are destroyed by birds the morning following the flight. The English sparrow has been observed by Mr. Kirkland to kill large numbers of the moths which remained about the lamps by pulling off the wings and devouring the bodies.

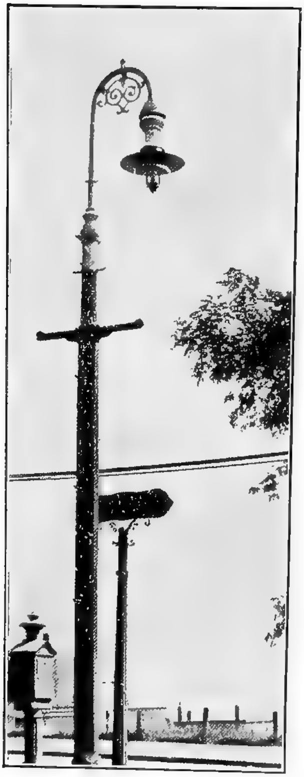


FIG. 6.—Brown-tail moths on electric light pole, Somerville, Mass., July 2, 1908. (From Kirkland.)

POISONING EFFECT OF BROWN-TAIL HAIRS.

From the time this insect was first found in Somerville numerous reports were received that the caterpillars were poisonous to human beings. Many people were severely affected with what was termed "the brown-tail rash," and much complaint arose on that account.

The best explanation of the trouble was that the barbed hairs of the caterpillars (fig. 7), when they came in contact with human skin, caused severe irritation. The scratching to relieve this itching forced the hairs farther into the tissue, which resulted in a slight swelling and an intense burning and stinging sensation.

When the housewife swept the caterpillars from the porch or brushed down the cocoons, which are interlaced with larval hairs, many were broken, and as a result severe cases of brown-tail rash followed.

The moths are provided with these barbed hairs, but to a less extent than the larvæ, and cases of poisoning have been reported during the flight of moths in the summer.

Broken hairs which float in the air when the caterpillars, webs, or cocoons are disturbed also cause severe internal irritation and poisoning if the dust is inhaled or swallowed in any considerable quantities. The poisoning has caused very serious illness to men engaged in the work against the moths, in the field, and at the Parasite Laboratory, and each year many are obliged to seek other employment, and not a few have been under a physician's care. The death of one man was due to severe internal poisoning contracted while employed on the work, particularly while turning burlaps.

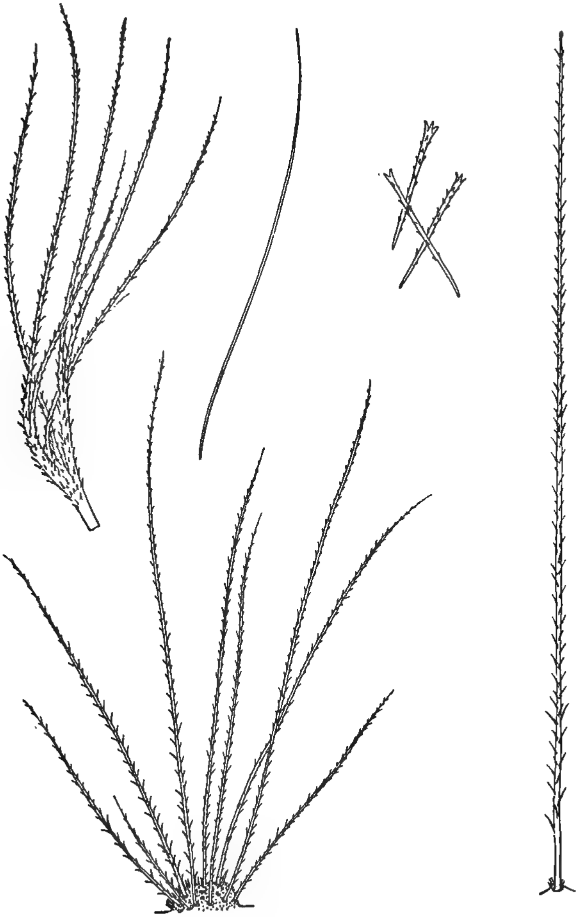


FIG. 7.—Hairs of the caterpillar of the brown-tail moth, highly magnified. (Adapted from Kirkland.)

Underclothes and bedding should not be put out upon the line during the caterpillar season, as the floating hairs may alight on such articles, which, when used, may result in serious poisoning.

During the year 1906 a careful study of this dermatitis was made by Dr. E. E. Tyzzer, of the Harvard Medical School, and a report was published by him.[a]

He concludes from his investigation that the barbed hairs not only cause a mechanical irritation but that they contain a poison which acts directly on the corpuscles of the blood. This results in a breaking down of the corpuscles to a certain extent and in their assuming a jagged outline instead of a circular one.

Such a multitude of people have suffered from this form of poisoning that many remedies have been prepared and sold which are warranted to give relief. During the summer metropolitan newspapers and many of the smaller papers in New England contain advertisements of remedies for the brown-tail rash. The trouble is more serious during hot weather, when persons are perspiring freely, and the skin at this time seems less resistant to the entrance of the spines.

Some of the advertised remedies give a certain measure of relief, but none of the remedies suggested is wholly efficacious. Applications which are cooling to the skin, such as witch-hazel or alcohol, serve to allay the irritation to some extent and reduce the suffering caused by the poison.

The internal irritation which is caused by breathing or swallowing the poisonous hairs is often very serious and no effective remedy has been found.

NATURAL ENEMIES OF THE GIPSY AND BROWN-TAIL MOTHS NATIVE TO AMERICA.

Aside from the experimental work on insecticides and a careful, detailed study of all phases of the life history and habits of the gipsy and brown-tail moths, considerable time was devoted by the Massachusetts authorities to an investigation of the native natural enemies which attack them in the field.

Both species are partially controlled in Europe by parasites and predaceous enemies, and it was desirable to ascertain if the closely related beneficial species in this country were showing any marked tendency toward controlling the pests.

Field observations on birds were made by Mr. Forbush, who was ably assisted in this work by Messrs. J. A. Farley and F. H. Mosher, the late Charles E. Bailey, and numerous other careful observers. A large number of native insectivorous birds were found feeding on the gipsy moth. Many of the observations have been published in the report by Forbush and Fernald already cited.

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[a] In Second Annual Report of the Superintendent for Suppressing the Gypsy and the Brown-tail Moths, Boston, 1907, pp. 154–168.

Unfortunately, conditions in the territory infested were not very favorable to the increase of insectivorous birds, and this, of course, served to limit their activities and usefulness. A few species, among which may be mentioned the crow, while destroying many of the larvæ, undoubtedly aided the spread of the gipsy moth by dropping live caterpillars in uninfested sections.

Field observations were made and work in rearing the insect enemies of these moths was carried on by Messrs. A. H. Kirkland, A. F. Burgess, F. H. Mosher, and others.

A few species of hymenopterous and dipterous parasites were found working in the field and small numbers of the adults were reared at the insectary. Among the predaceous enemies were several species of beetles (Carabidæ) and stink bugs (Pentatomidæ) which were found feeding on the larvæ in the field and were studied in detail in the laboratory.

Although not an insect, the common toad should be mentioned as doing valuable work in destroying such specimens of the insects as came within its reach.

The rapid development and unprecedented injury caused by the gipsy moth after the state work was abandoned show conclusively that native natural enemies are entirely unable to cope with the situation.

PROGRESS OF THE STATE WORK IN MASSACHUSETTS, 1890–1900.

The administration of any extensive public work almost invariably arouses more or less antagonism, and the gipsy moth work was no exception in this respect. In compliance with the provisions of the law which provided for the extermination of this insect, no effort was made to introduce its parasites or natural enemies from abroad, as it would have been necessary to allow extensive colonies of the insect to remain untreated in order to give introduced parasites an opportunity to become established. Some criticism was occasioned by this manner of handling the work and in addition to this many property owners in sections of the State which were not infested failed to see the necessity for making large appropriations to destroy the insect. Active opposition developed in some sections of the infested territory, which was occasioned by ignorance as to the methods of carrying on the work.

Realizing that the work was of a different character from any that had been attempted previously, and that new methods and devices must be employed to handle the problem with any degree of success, great effort was made to test in a practical way any suggestions that seemed to have a bearing on reducing the expense of making the work more effective.

From the time the first state appropriation was made until the close of the work the gipsy moth committee procured expert opinions from the leading entomologists of the country, and during this period a large number of prominent scientists visited the territory, inspected the work, and without exception reported that the extermination of the gipsy moth was not only practicable but feasible and that it could be accomplished provided proper financial support was given the work. In the winter of 1894–1895 an unsuccessful attempt was made to secure national aid in exterminating this insect. A bill, carrying an appropriation for $40,000, was passed by the United States Senate, but it was defeated in the conference committee. During the session of Congress, 1896–1897, an appropriation was made for an investigation of the ravages of the gipsy moth in this country. Dr. L. O. Howard, Chief of the Bureau of Entomology, made several visits to the infested territory and thoroughly examined the conditions and the work which was being done. Mr. C. L. Marlatt, first assistant entomologist, also made a visit to the infested district and investigated the condition of the territory. The report of Doctor Howard[a] highly commended the work which had been done and stated his opinion that the extermination of the gipsy moth could be accomplished. During the winter of 1897 the Massachusetts Society for the Promotion of Agriculture secured the services of Dr. John B. Smith, state entomologist of New Jersey, to investigate the work and report the conditions found. The report strongly favored continuing the work and expressed the opinion that the insect could be exterminated if sufficient funds were appropriated, but the society did not publish the report in full. The condition of the infested territory continued to improve. The residential sections were in excellent condition in 1899, although small numbers of the insect were present. Many woodland colonies had been entirely exterminated, as evidenced by the fact that none of the insects had been found for three successive years. The spread of the brown-tail moth, however, continued each year and little hope was entertained of being able to exterminate it.

DISCONTINUANCE OF THE STATE WORK IN MASSACHUSETTS.

At the annual session of the legislature in the winter of 1900 a special committee was appointed to investigate the gipsy-moth work. After numerous hearings it was reported that the insect need not be considered a serious pest, and further that "we find no substantial proof that garden crops or woodlands have suffered serious or lasting injury or are likely, with that precaution or oversight which prudent owners are disposed to give their own interests, to be subjected to that devastation which one would have the right to anticipate from these reports. It appears to us that the fears of the farmers throughout the State have been unnecessarily and unwarrantably aroused, evidently for the purpose of securing the effect of those fears upon the matter of annual appropriations * * * We do not share these exaggerated fears and the prophesies of the devastation and ruin are unwarranted and in the most charitable view are but the fallacies of honest enthusiasts." As a result of the report of this committee no further appropriation was made for carrying on the work. The tools and equipment which had been used were ordered sold, and the insect was allowed to develop without restriction.

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[a] Bul. 11, n. s., Division of Entomology, U. S. Dept. of Agriculture.

CONDITIONS IN THE INFESTED TERRITORY AT THE CLOSE OF THE STATE WORK.

As before stated, the area found infested in 1891 included 30 towns and cities, covering 200 square miles. Between the years 1891 and 1900 isolated colonies were discovered beyond these limits in Brookline, Burlington, Danvers, Georgetown, Manchester, Newton, and Lincoln. These infestations were given special attention and several of them were practically exterminated before the work was discontinued. Vigorous measures were enforced over the entire infested territory and all of the worst colonies, including those in the woodlands, had been reduced to such an extent that the extermination of the insect was practically assured. Several towns had been completely cleared of the insect, and the residential sections showed no defoliation, and considerable search was necessary for a nonexpert to secure specimens of the insect.

FUNDS EXPENDED BY THE STATE DURING THE PROGRESS OF THE WORK.

During the progress of the work the following amounts were asked for and received for the suppression of the pest:

Year.	Amount asked.	Amount appropriated.
1890	$50,000	$50,000
1891	50,000	50,000
1892	75,000	75,000
1893	165,000	100,000
1894	165,000	100,000
1895	200,000	150,000
1896	200,000	100,000
1897	200,000	150,000
1898	200,000	200,000
1899	200,000	200,000
1900	200,000	....
Total expenditure	....	1,175,000

RESULTS OF DISCONTINUANCE OF THE WORK.

During the years 1900 and 1901 little notable injury was caused by the gipsy moth and little attention was paid to it.

In the winter of 1902 a small pamphlet was issued by the state board of agriculture setting forth the fact that the moth was increasing to an alarming extent in many of the wooded districts and predicting that unless all signs failed enormous injury would result. Mention was also made of the fact that about 4 square miles had been found infested in Providence, R. I., during the summer of 1901. This was the first infestation found outside the State of Massachusetts, and from its location it was believed that the insects had been purposely liberated by some malicious person.

At this time the brown-tail moth had spread rapidly in a northeast direction throughout eastern Massachusetts and into New Hampshire and Maine. Already many persons were being poisoned severely by the caterpillars, especially in the sections around Boston, where the moths were becoming abundant.

During the next two years the gipsy moth increased to such an extent that thousands of acres of woodland were defoliated. The caterpillars appeared in such swarms as to denude the orchards and ornamental trees in most of the sections which were previously infested. Large areas of pine timber died as a result of the work of the pest, and real estate values rapidly depreciated in the worst infested sections.

Valuable shade trees were killed outright or injured to such an extent that they had to be cut down, owing to their unsightly appearance.

The caterpillars swarmed into the houses, covered fences, and spun down from the trees upon the clothing of pedestrians, so that they became an unbearable nuisance. Some of them fell upon teams or automobiles and were carried long distances and served to establish new colonies. Stories of the immense numbers of caterpillars seem almost incredible. On several occasions trolley cars were prevented from running until the tracks were cleared of the crushed and swarming insects. The following spring it was necessary for many of the motormen to wear veils to keep their eyes and faces free from the caterpillars which swarmed from the trees. Acres of forest died as the result of the ravages of the caterpillars, the injury including both hardwood trees and conifers. In fact, the conditions which existed in Medford in 1890 were very mild compared with those in the area infested in 1904. To make matters worse, the brown-tail moth appeared at this time in alarming numbers. Thousands of persons were poisoned by the hairs of this insect, and young children especially suffered severely. Physicians reported many cases of this kind, and general appeal was made that something be done to abate the nuisance.

During the summer of 1904, Mr. C. L. Marlatt, first assistant entomologist of this Bureau, visited the infested territory and strongly urged that the matter be given immediate attention. In his report on the conditions existing, which has been published in Circular 58, Bureau of Entomology, he stated that at the time his observations were made the property owners in the badly infested section were at a conservative estimate spending more than $200,000 annually in fighting the gipsy moth, and that the results were far from satisfactory owing to the fact that the work was not carried on in a systematic manner. The amount cited represents the largest annual appropriation which had been made by the State before the work was discontinued.

All these factors led to the formation of many local associations which had for their object the destruction of the moths. Many of the infested towns and cities appropriated funds which were used to protect the trees, and the citizens, after becoming thoroughly aroused, fought the pests vigorously as a matter of self-protection. The work, however, was far from effective because it was not properly organized and undertaken in a systematic manner, and while many owners had their premises well taken care of, their efforts were largely nullified by the negligence of careless neighbors or nonresident property owners. This was particularly true on estates adjoining wooded areas which had a small market value.

The brown-tail moth, which had confined most of its energies up to the present time to feeding on fruit and ornamental trees, was now found widely scattered throughout the woodlands, and the trees, especially oaks, in many regions were thoroughly infested with webs of the pest.

STATE WORK RESUMED IN MASSACHUSETTS.

So serious was the situation and so urgent were the appeals for assistance that the Massachusetts legislature took action in the matter in 1905. The law was amended in 1906 and is given in full, as it has formed the basis for similar laws in other States.

[Chap. 381, acts of 1905, as amended by chap. 268, acts of 1906.]

AN ACT To provide for suppressing the gypsy and brown tail moths.

Be it enacted, etc., as follows:

SECTION 1. For the purposes of this act the pupæ, nests, eggs, and caterpillars of the gypsy and brown tail moths and said moths are hereby declared public nuisances, and their suppression is authorized and required; but no owner or occupant of an estate infested by such nuisance shall by reason thereof be liable to an action, civil or criminal, except to the extent and in the manner and form herein set forth.

SEC. 2. The governor, by and with the consent of the council, shall appoint a superintendent for suppressing the gypsy and brown tail moths and shall determine his salary. The governor may, with the consent of the council, remove said superintendent at any time for such cause as he shall deem sufficient. In case of the death, removal, or resignation of the superintendent the governor shall forthwith appoint a successor. On or before the third Wednesday in January in each year the superintendent shall make a report of his proceedings to the general court, which shall be a public document and shall be printed. Said report shall separate so far as is practicable the expenditures on work against the gypsy moth from those on work against the brown tail moth in each city and town.

Sec. 3. [As amended by section 1, chapter 268, acts of 1906.] The said superintendent shall act for the Commonwealth in suppressing said moths as public nuisances, in accordance with the provisions of this act. For this purpose he shall establish an office and keep a record of his doings and of his receipts and expenditures, and may, subject to the approval of the governor, make rules and regulations governing all operations by cities, towns or individuals under this act. He may employ such clerks, assistants and agents, including expert advisers and inspectors, as he may deem necessary and as shall be approved by the governor. He may make contracts on behalf of the Commonwealth; may act in cooperation with any person, persons, corporation, or corporations, including other States, the United States, or foreign governments; may conduct investigations and accumulate and distribute information concerning said moths; may devise, use and require all other lawful means of suppressing or preventing said moths; may lease real estate when he deems it necessary, and, with the approval of the board in charge, may use any real or personal property of the Commonwealth; may at all times enter upon the land of the Commonwealth or of a municipality, corporation, or other owner or owners, and may use all reasonable means in carrying out the purposes of this act; and, in the undertakings aforesaid, may, in accordance with the provisions of this act, expend the funds appropriated or donated therefor; but no expenditure shall be made or liability incurred in excess of such appropriations and donations.

Sec. 4. [As amended by section 2, chapter 268, acts of 1906.] Cities and towns by such public officer or board as they shall designate or appoint, shall, under the advice and general direction of said superintendent, destroy the eggs, caterpillars, pupæ, and nests of the gypsy and brown tail moths within their limits, except in parks and other property under the control of the Commonwealth, and except in private property, save as otherwise provided herein. When any city or town shall have expended within its limits city or town funds to an amount in excess of five thousand dollars in any one calendar year, in suppressing gypsy or brown tail moths, the Commonwealth shall reimburse such city or town to the extent of fifty per cent of such excess above said five thousand dollars.

Cities or towns, where one twenty-fifth of one per cent of the assessed valuation of real and personal property is less than five thousand dollars, and where the assessed valuation of real and personal property is greater than six million dollars, shall be reimbursed by the Commonwealth to the extent of eighty per cent of the amount expended by such cities or towns of city or town funds in suppressing the gypsy and brown tail moths in any one calendar year, in excess of said one twenty-fifth of one per cent.

In the case of towns where the assessed valuation of real and personal property is less than six million dollars, after they have expended in any one calendar year town funds to an amount equal to one twenty-fifth of one per cent of their assessed valuation of real and personal property, the Commonwealth shall expend within the limits of such towns, for the purpose of suppressing the gypsy and brown tail moths, such an amount in addition as the superintendent with the advice and consent of the governor shall recommend. Disbursements made by said last named towns in excess of said one twenty-fifth of one per cent shall be reimbursed by the Commonwealth every sixty days; but in the case of all others the Commonwealth shall reimburse cities and towns annually according to the provisions of this act.

No city or town shall be entitled to any reimbursement from the Commonwealth until it has submitted to the auditor of the Commonwealth itemized accounts and vouchers showing the definite amount expended by it for the purpose of this act; nor shall any money be paid out of the treasury of the Commonwealth to cities or towns, pursuant to the provisions of this act, until said vouchers and accounts have been approved by the superintendent and the auditor of the Commonwealth.

For the purposes of this section the years nineteen hundred and five and nineteen hundred and seven shall be considered half years, and the valuation for the year nineteen hundred and four shall be taken as a basis.

SEC. 5. [As amended by section 3, chapter 268, acts of 1906.] When, in the opinion of the superintendent, any city or town is not expending a sufficient amount for the abatement of said nuisance, or is not conducting the necessary work in a proper manner, then the superintendent shall, with the advice and consent of the governor, order such city or town to expend such an amount as the superintendent shall deem necessary, and in accordance with such methods as the superintendent, with the consent of the governor, shall prescribe: *Provided,* That no city or town where the assessed valuation of real and personal property exceeds six million dollars shall be required to expend, exclusive of any reimbursement received from the Commonwealth, during any one full year more than one fifteenth of one per cent of such valuation, and that no town where the assessed valuation of real and personal property is less than six million dollars shall be required to expend, exclusive of any reimbursement received from the Commonwealth, during any one full year more than one twenty-fifth of one per cent of such valuation. For the purposes of this section the valuation of the year nineteen hundred and four shall be used.

Any city or town failing to comply with the directions of the said superintendent in the performance of said work within the date specified by him shall pay a fine of one hundred dollars a day for failure so to do; said fine to be collected by information brought by the attorney-general in the supreme judicial court for Suffolk County.

SEC. 6. [As amended by section 4, chapter 268, acts of 1906.] The mayor of every city and the selectmen of every town shall, on or before the first day of November in each year, and at such other times as he or they shall see fit, or as the state superintendent may order, cause a notice to be sent to the owner or owners, so far as can be ascertained, of every parcel of land therein which is infested with said moths; or, if such notification appears to be impracticable, then by posting such notice on said parcels of land, requiring that the eggs, caterpillars, pupæ and nests of said moths shall be destroyed within a time specified in the notice.

When, in the opinion of the mayor or selectmen, the cost of destroying such eggs, caterpillars, pupæ, and nests on lands contiguous and held under one ownership in a city or town shall exceed one half of one per cent of the assessed value of said lands, then a part of said premises on which said eggs, caterpillars, pupæ or nests shall be destroyed may be designated in such notice, and such requirement shall not apply to the remainder of said premises. The mayor or selectmen may designate the manner in which such work shall be done, but all work done under this section shall be subject to the approval of the state superintendent.

If the owner or owners shall fail to destroy such eggs, caterpillars, pupæ or nests in accordance with the requirements of the said notice, then the city or town, acting by the public officer or board of such city or town designated or appointed as aforesaid, shall, subject to the approval of the said superintendent, destroy the same, and the amount actually expended thereon, not exceeding one half of one per cent of the assessed valuation of said lands, as heretofore specified in this section, shall be assessed upon the said lands; and such an amount in addition as shall be required shall be apportioned between the city or town and the Commonwealth in accordance with the provisions of section four of this act. The amounts to be assessed upon private estates as herein provided shall be assessed and collected, and shall be a lien on said estates, in the same manner and with the same effect as is provided in the case of assessments for street watering.

Sec. 7. [As amended by section 5, chapter 268, acts of 1906.] If, in the opinion of the assessors of a city or town, any land therein has received, by reason of the abatement of said nuisances thereon by said superintendent or by said city or town, a special benefit beyond the general advantage to all land in the city or town, then the said assessors shall determine the value of such special benefit and shall assess the amount thereof upon said land: *Provided,* That no such assessment on lands contiguous and held under one ownership shall exceed one half of one per cent of the assessed valuation of said lands; and *Provided,* That the owner or owners shall have deducted from such assessment the amount paid and expended by them during the twelve months last preceding the date of such assessment toward abating the said nuisances on said lands, if, in the opinion of the assessors, such amount has been expended in good faith. Such assessment shall be a lien upon the land for three years from the first day of January next after the assessment has been made, and shall be collected under a warrant of the assessors to the collector of taxes of such city or town, in the manner and upon the terms and conditions and in the exercise of the powers and duties, so far as they may be applicable, prescribed by chapter thirteen of the Revised Laws relative to the collection of taxes.

Real estate sold hereunder may be redeemed within the time, in the manner, and under the provisions of law, so far as they may be applicable, set forth in chapter thirteen of the Revised Laws for the redemption of land sold for taxes.

A person aggrieved by such assessment may appeal to the superior court for the county in which the land lies, by entering a complaint in said court within thirty days after he has had actual notice of the assessment, which complaint shall be determined as other causes by the court without a jury. The complaint shall be heard at the first sitting of said court for trials without a jury after its entry; but the court may allow further time, or may advance the case for speedy trial, or may appoint an auditor as in other cases. The court may revise the assessment, may allow the recovery back of an amount wrongfully assessed which has been paid, may set aside, in a suit begun within three years from the date thereof, a collector's sale made under an erroneous assessment, may award costs to either party and may render such judgment as justice and equity require.

If, in the opinion of the assessors, the owner of an estate upon which an assessment as aforesaid has been made is, by reason of age, infirmity or poverty unable to pay the assessment, they may upon application abate the same. Every city or town in rendering an account to the state auditor as provided for in section four of this act shall deduct from such amount as it has expended the total amount it has received for work performed under section six of this act during the term covered by the account: *Provided,* Such work was performed under such conditions as require reimbursement in whole or in part by the state.

Sec. 8. To meet the expenses incurred under authority of this act, there shall be allowed and paid out of the treasury of the Commonwealth, during the period up to and including May first, nineteen hundred and seven, the sum of three hundred thousand dollars. Of this amount seventy-five thousand dollars may be expended during the calendar year nineteen hundred and five; one hundred and fifty thousand dollars, and any unexpended balance of the previous year, may be expended during the calendar year nineteen hundred and six; and seventy-five thousand dollars, and any unexpended balance of the previous years, may be expended during the calendar year nineteen hundred and seven, up to and including May first.

SEC. 9. An additional sum of ten thousand dollars in each of the years nineteen hundred and five, nineteen hundred and six and nineteen hundred and seven may, in the discretion of the state superintendent, be expended by him for experimenting with parasites or natural enemies for destroying said moths, and any unexpended balance of any year may be expended in the subsequent years.

SEC. 10. Chapter two hundred and ten of the acts of the year eighteen hundred and ninety-one and sections one and two of chapter five hundred and forty-four of the acts of the year eighteen hundred and ninety-eight and section two of chapter fifty-seven of the acts of the year nineteen hundred and two, are hereby repealed.

SEC. 11. [As amended by section 6, chapter 268, acts of 1906.] A person who willfully resists or obstructs the superintendent or an official of a city or town, or a servant or agent duly employed by said superintendent or by any of said officials, while lawfully engaged in the execution of the purposes of this act, or who knowingly fails to comply with any of the rules or regulations issued by said superintendent, shall forfeit a sum not exceeding twenty-five dollars for each offence.

SEC. 12. Valuations of real and personal property of the year nineteen hundred and four shall govern the provisions of this act.

SEC. 13. This act shall take effect upon its passage.

Approved May 8, 1905.

This law is now in force, with a few minor administrative amendments. In the spring of 1909, following the resignation of the state superintendent, an amendment was enacted placing the work in charge of the state forester.

The law provides a cooperative plan for fighting the gipsy moth and brown-tail moth by which each infested city or town is required to appoint a local superintendent and to expend annually a certain amount, based on its valuation, and, after this has been done, subject to the approval of the state forester, reimbursement is allowed by the State in amounts graduated according to assessed valuation. Thus the large cities are required to expend a larger amount before receiving any reimbursement from the State, and then receive a smaller percentage than the towns with small valuations and large areas of woodland, which are very expensive to treat.

Cities and towns with an assessed valuation on real and personal property of $12,500,000 or more shall, after expending $5,000 in any one year, be reimbursed 50 per cent of all further expenditures.

Cities and towns where the assessed valuation ranges between $6,000,000 and $12,500,000, after expending one twenty-fifth of 1 per cent of the valuation, are reimbursed 80 per cent of all further expenditures.

Cities and towns where the assessed valuation falls below $6,000,000 are required to expend one twenty-fifth of 1 per cent and are reimbursed in full for all further expenditures.

The property owner is required to clear his premises of the insects and to expend therefor not more than one-half of 1 per cent, or $5 per $1,000, of the assessed valuation. In case of failure to do this work after proper notice has been served, the premises may be treated by the town officials and the cost, not to exceed the above amount, may be levied and collected in taxes.

The whole purport of the law is to divide the burden between the property owner, the infested municipalities, and the State, and to place the entire work under state supervision in order to secure uniformity of methods and economy of expenditure.

The law provided for an appropriation of $75,000 for the year 1905, $150,000 for 1906, and $75,000 for 1907. An appropriation of $10,000 a year was also made for a period of three years to provide for the expense of introducing the parasites and natural enemies of these insects from abroad and for their propagation and dissemination in the infested district. The latter work was organized in coöperation with the United States Bureau of Entomology under the direction of Dr. L. O. Howard, Chief of the Bureau.

On May 15, 1905, Mr. A. H. Kirkland was appointed state superintendent by Hon. W. L. Douglas, then governor of the State. The wisdom of this appointment was soon apparent in the results secured in organizing a most difficult piece of work and in training a skilled force of men for efficient service, and the State was very fortunate in being able to procure the services of a well-trained entomologist, who brought to the work a thorough knowledge of the conditions to be met, high scientific attainments, and rare executive ability—a combination seldom secured.

The work during the year 1905 consisted in organizing the moth forces in towns in the infested territory and sending the most expert men that could be employed by the central office into the outside districts to determine if the gipsy moth was present. As a result of a hurried inspection it was determined that 124 towns, covering an area of 2,224 square miles, were more or less infested, against 34 towns, covering an area of 359 square miles, in which the moth was known to exist in 1900, when the state work was discontinued. The gipsy moth was also found in several towns north of the Massachusetts line in New Hampshire, to and including Portsmouth, while the colony at Providence, R. I., had increased to a considerable extent. Practically the same methods were used as those adopted when the old work was in progress, although, owing to the increased area infested and the extremely bad condition of the central district, it was necessary to abandon the idea of extermination and use all possible methods to control the insect and to prevent its further spread. The scouting operations which were carried on in the outside infested towns were, of course, done in a rather hurried manner on account of the great pressure of other work and the necessity for immediately taking active measures to destroy the moths in the badly infested towns and cities. Much effort was necessary in order to organize the work and secure a trained force of local men.

This large area, which included thousands of acres of badly infested woodland, was in a much worse condition than in 1904 and it soon became evident that heroic measures must be taken and an enormous amount of work done if any appreciable progress was to be made in preventing widespread injury.

A single case will serve as an illustration of the loss to owners of timber caused by the gipsy moth. A tract of woodland near the Bedford and Billerica town line, belonging to the Hosmer estate, was sought by a portable saw mill operator in 1907, who offered $6,000 for the wood and timber, but, as the owners wanted $6,500, the trade was dropped. The following winter, owing to the presence of the moths in large numbers, the lot was sold for about $3,000, and immediately cut, resulting in loss to the owners of at least 50 per cent in one year. At the time the state work ceased in 1900 this property was 4 miles outside of the infested area.

In 1906 the Massachusetts legislature added $150,000 to the appropriation already made for that year and united with the other New England States in an appeal to Congress to furnish aid.

The brown-tail moth was found to be present, in 1905, as far west as central Massachusetts. It also occurred in the southern counties in New Hampshire and along the coast, specimens having been reported from Eastport, Me., and St. John, New Brunswick. A single insect was found at Providence, R. I., during the year.

BEGINNING OF WORK BY THE NATIONAL GOVERNMENT.

The spread of the gipsy and brown-tail moths caused much alarm in the New England States, and in the fall of 1905 an appeal was made to Congress to assist in the work of controlling these pests. The movement was supported by delegations from Maine, where the work of the year had shown that an area of approximately 4,000 square miles was infested with the brown-tail moth and where energetic measures were being taken to control the insect; by New Hampshire, which was seriously infested with both pests; by Massachusetts, where heroic measures were being taken to control the situation; and by Rhode Island, where a serious infestation of the gipsy moth existed.

On December 4, 1905, a bill was introduced by Representative Ernest W. Roberts, of Massachusetts, providing for an appropriation of $250,000, to assist in preventing the spread and securing the control of these pests. The urgent necessity for action was forcibly brought out by a report from Dr. W. E. Britton, state entomologist of Connecticut, in March, 1906, that a few egg clusters of the gipsy moth had been found in Stonington, in that State.

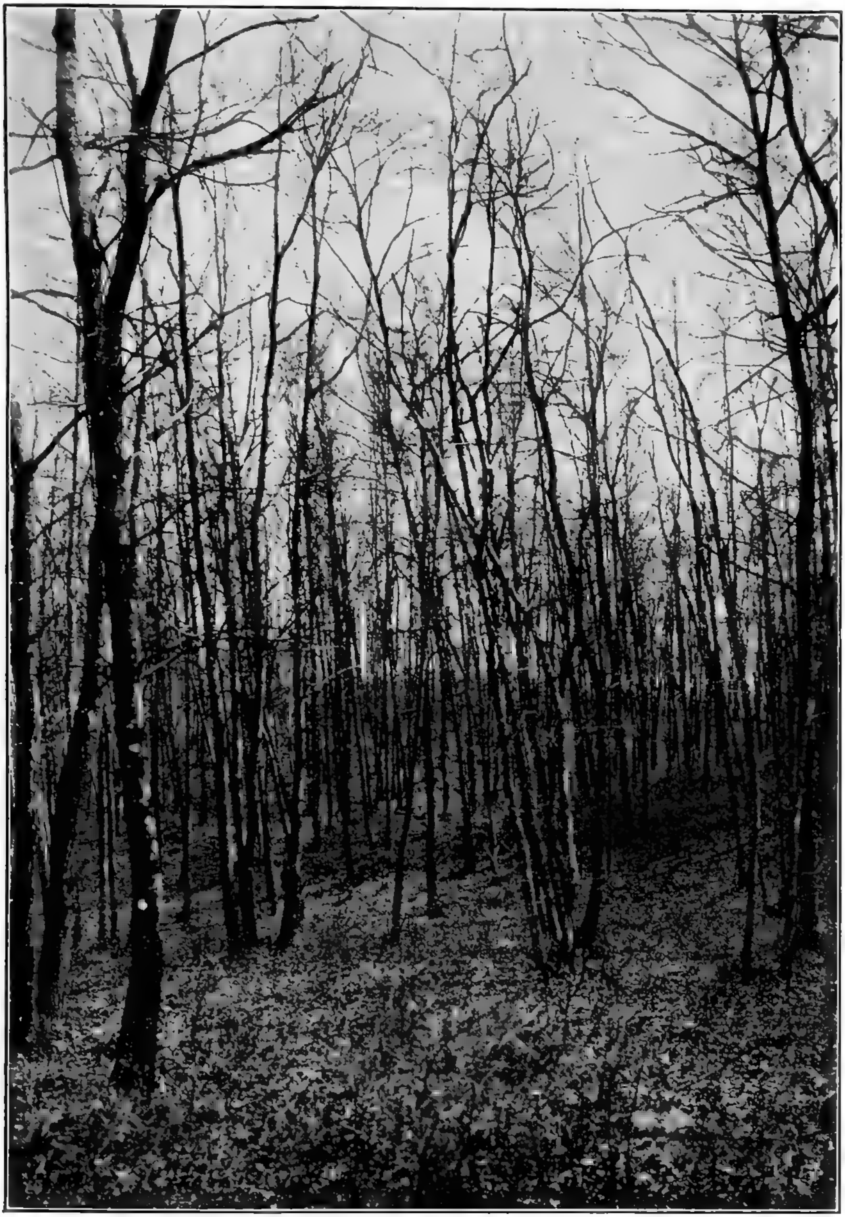
Owing to the fact that approximately 300 square miles was thickly infested in eastern Massachusetts, ample opportunity was offered for the larvæ to be carried many miles during the early summer, and thus the whole country was in danger of becoming infested.

Later in the season $82,500 was appropriated by Congress. The work was put under the direction of Dr. L. O. Howard, Chief of the Bureau of Entomology, and Mr. D. M. Rogers, then first assistant to state superintendent Kirkland, was appointed special field agent of the Bureau in charge of the field work in New England. This appropriation became available July 1, 1906, and after a conference between the Chief of the Bureau of Entomology, the superintendent of the moth work in Massachusetts, and the special field agent of the Bureau it was decided that the most valuable results could be secured with this appropriation by at once clearing as many roadsides as possible in the thickly infested and much traveled section of Massachusetts. Arrangements were also made to prevent dissemination of the gipsy moth in the outside territory as far as the limited appropriation would allow. A force of 22 men which had been working in the infested district in Rhode Island was carried on the pay roll from July 23, 1906, to May 15, 1907, although the number at the latter date had been reduced to 9 men, so that work in that State could be continued until the state funds were available.

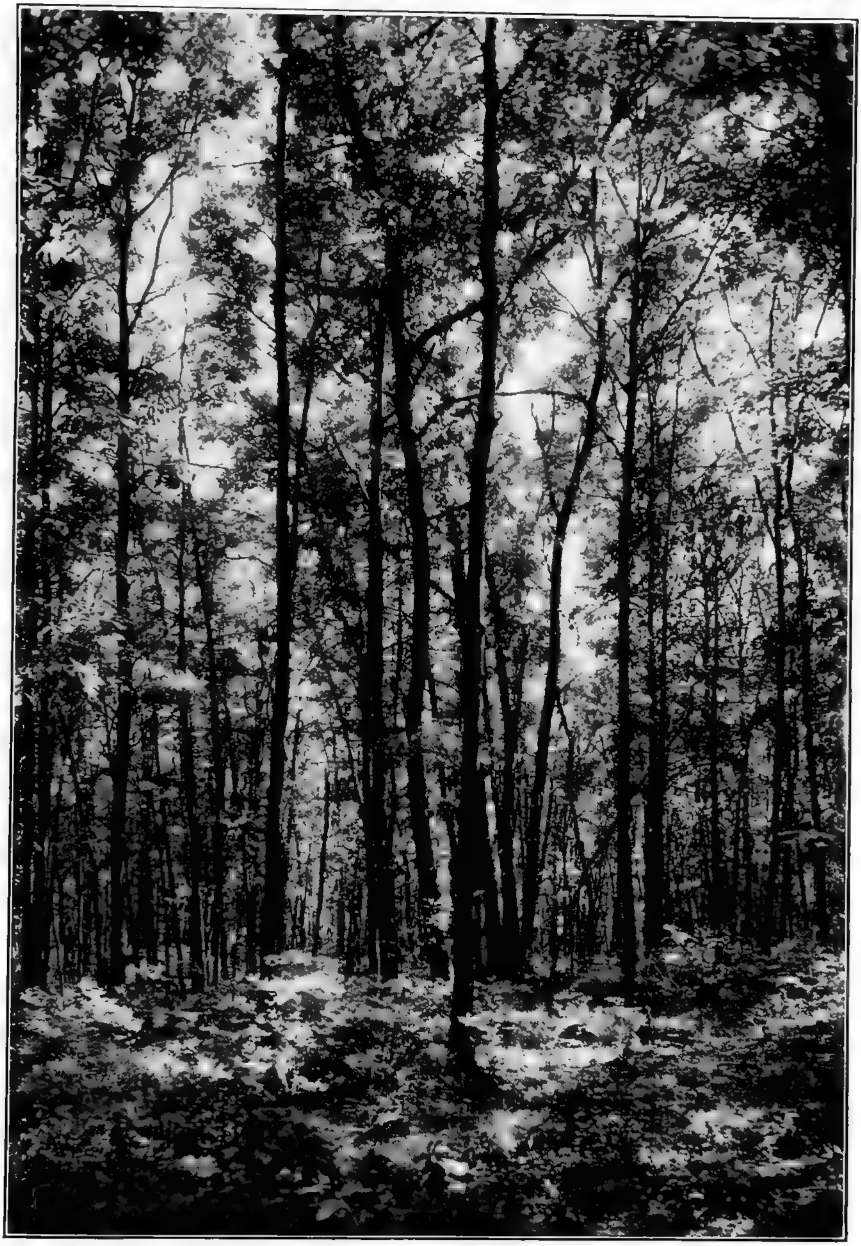
Later in the season scouting parties were organized and a limited amount of work done in the southern parts of New Hampshire and Maine. A more detailed account of this work will be given later in this report.

Owing to the severe infestation in the district around Boston (see Pl. V in comparison with Pl. VI), and to the fact that practically all of the main highways were being used continually during the caterpillar season by automobiles, it seemed necessary to keep the roadsides free from caterpillars if a general dissemination of the pests to distant points was to be prevented. Traffic between Boston and its suburbs, the shore resorts along the coast, and the vacation places in New Hampshire, is particularly heavy during the early summer. At the time of the serious outbreak of the gipsy moth in 1890 the spread of the insect was made possible chiefly by means of teams or carriages that passed through the infested district, and these seldom traveled more than 20 miles in a single day. With the use of the automobile the daily travel often covers a hundred or more miles, so that the danger of spread to remote districts was greatly increased; in fact, recent inspections have shown that the spread of the insect can often be traced directly to this means of conveyance.

A building was rented at Medford at a point within easy reach of the badly infested section where work was to be carried on, the necessary tools and supplies (figs. 8, 9) were installed, and arrangements made for actively beginning the campaign against the moths. Mr. Harry W. Vinton was selected as a special agent to take charge of



WOODLAND AT LEXINGTON, MASS., COMPLETELY DEFOLIATED BY THE GIPSY MOTH. (ORIGINAL.)



SAME WOODLAND AT LEXINGTON, MASS., AS THAT SHOWN IN PLATE V, THE FOLLOWING YEAR, ILLUSTRATING BENEFICIAL EFFECTS OF CONTROL WORK. (ORIGINAL.)

active operations in the field. Mr. Vinton had served for several years on the gipsy moth work when it was being conducted by the Massachusetts state board of agriculture, and from his long experience and thorough knowledge of the pest and the proper methods of treatment, as well as his familiarity with the infested region, it was possible to begin active operations without delay.

Several trunk roads in Melrose, Saugus, and Wakefield which extended through badly infested woodland were selected, and active cutting operations begun. Crews of men were employed to cut out the brush and worthless trees and to thin the sound timber on a strip 100 feet wide on each side of the highway. The brush was then burned and the egg clusters on the remaining trees and ledges were creosoted. (See fig. 10.) Very little if any work was planned or has been carried out up to the present time in residential parts of the infested district, as the town and city officials, acting under state law, usually keep the trees in such sections fairly free from infestation. The cutting out of these roadways is simply for the purpose of preparing the way for a thorough and economical treatment. It is usually necessary to carefully prune many of the trees in the treated area, and in some cases where they are of special value the cavities in hollow trees are closed with cement, covered with zinc, or sealed with a wooden plug, so that egg clusters can not be deposited in such places, where it is extremely difficult to treat them. In the spring the trees are banded, and burlaps are often used for this purpose. Another method which has come into favor since the gipsy moth work was resumed in Massachusetts is to apply a band

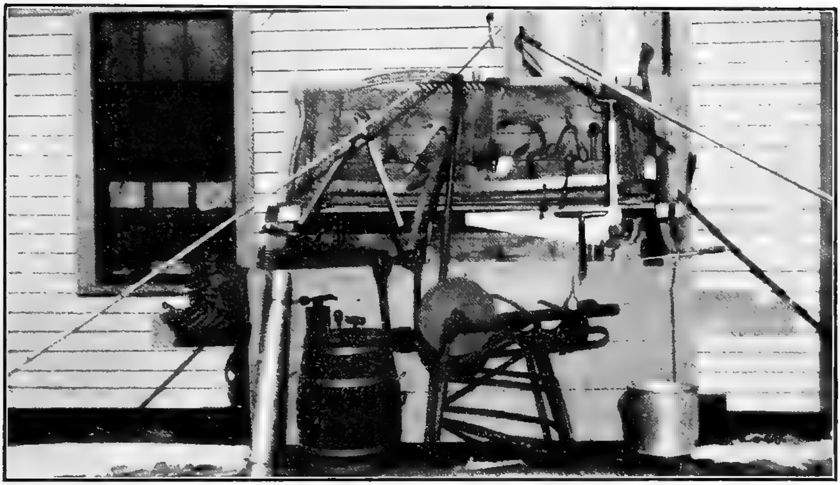


FIG. 8.—Equipment for roadside work against the gipsy moth, used by employees of the Bureau of Entomology. (Original.)

of tanglefoot to the trunks of the trees before the eggs hatch. (See fig. 11.) Rough-bark trees should be scraped where this material is to be placed, so that the surface will be smooth enough to apply the band evenly with a wooden paddle. Care should be taken not to remove the inner bark so that the living wood will be exposed. If the tree tanglefoot can be applied evenly, no scraping should be done. This material will remain sticky for several weeks, and prevent the caterpillars from ascending, but the best practice is to draw a comb through the band as the workman walks around the tree. This brings fresh material to the surface and removes any foreign substances which may have collected. The caterpillars are obliged to feed on what low growth remains on the ground and if this has been well sprayed they are soon destroyed. Aside from the roads already mentioned a considerable amount of roadside work was done in the towns of Malden, Lynnfield, Lynn, Peabody, Woburn, Lexington, Burlington, Waltham, and Belmont, and the strips cut out during the fall of 1906 and the spring of 1907 and prepared for spring and summer treatment aggregated about 65 miles. Late in April and early in May, 1907, the trunks of the trees in all these strips were banded with tanglefoot to prevent the caterpillars from climbing the trees, as well as to keep such larvæ as migrated from the woodland back of the strips from destroying the foliage. After the caterpillars hatched the strips were sprayed with arsenate of lead, which was used at the rate of 10 pounds to 100 gallons of water. Previous to this time one small and three large spraying machines operated by gasoline engines had been secured. Owing to the lim-

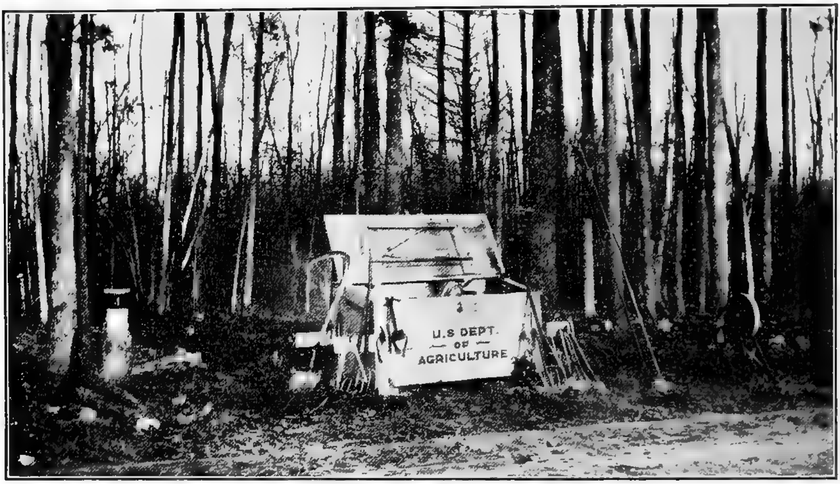


FIG. 9.—Roadside where thinning operations are being carried on, showing tools and equipment used in the work. (Original.)

ited length of time that the insect is in the caterpillar stage it is necessary to provide equipment so that a large area can be thoroughly sprayed in a short time. This renders impracticable the use of hand outfits for such extensive work. The sprayers used had a tank capacity of between 500 and 600 gallons, and it was possible to treat many acres in a single day. Since the work began a number of improvements have been made in spraying outfits used, which have rendered them more efficient and economical. In addition to the spraying the burlap and sticky bands on the trees were examined from time to time and the caterpillars crushed with steel-wire brushes. In the worst infested places it was necessary to go over the strips daily, and even then in some instances it was almost impossible to kill the caterpillars fast enough to prevent some defoliation on the back edge of the treated strips.

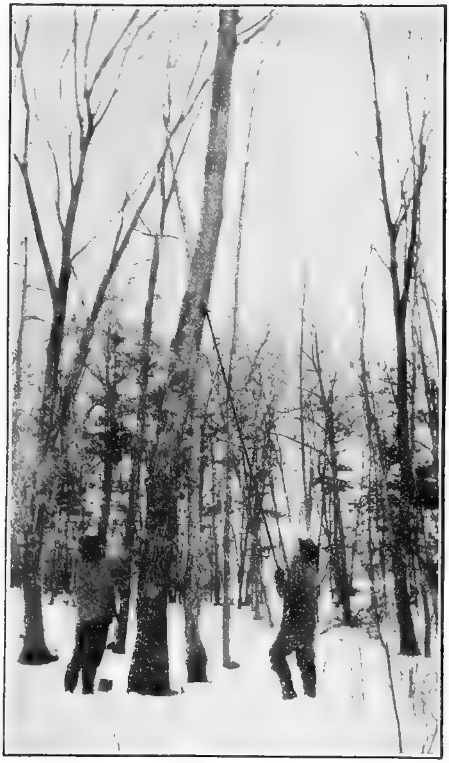


FIG. 10.—Employees of the Bureau of Entomology treating egg clusters of the gipsy moth with creosote, using an ordinary paint brush and a brush attached to a long pole. (Original.)

Early in the fall of 1906 a number of the more experienced men were selected and scouting operations were begun in a limited way in Maine, New Hampshire, and Connecticut. (See fig. 12, showing outfit used by gipsy moth scouts.) This work was continued until June, 1907, and a large number of towns were found infested. In the spring of 1907 it became evident that owing to the discovery of so many infested towns, a larger appropriation would be necessary in order to make anything like a careful examination of the outside territory. In May, 1907, Congress appropriated $150,000 for the purpose of carrying on the work, this sum being available for immediate use. Plans were at once made to clear more roadside areas in the worst infested sections and in the fall to scout thoroughly the towns north of the known infested region. Owing to the great increase in the amount of work which was to be taken up, the territory in

Massachusetts was divided into two sections. Mr. Vinton took charge of the crews in one of these sections, and Mr. David G. Murphy was appointed, June 17, to take charge of the crews in the other division. Mr. Murphy, like Mr. Vinton, had had long experience in fighting the gipsy moth in Massachusetts, and had proved by his previous work with the State to be very capable in taking charge of field work. The roadside work was continued in Massachusetts during the summer and fall, and by the next spring the mileage that had been cut out had been increased twofold over that of the previous year. The strips were treated in practically the same manner as already described and much benefit resulted from this work. Special effort was made in the fall to thoroughly scout the region outside of the towns known to be infested in New Hampshire. The work was handicapped to some extent by inability to secure men with sufficient training who were willing to take up this arduous work during the winter. The scouting, however, resulted in the discovery of 17 additional infested towns. Work of a similar character was carried on in Maine, where five more towns were found to be infested.

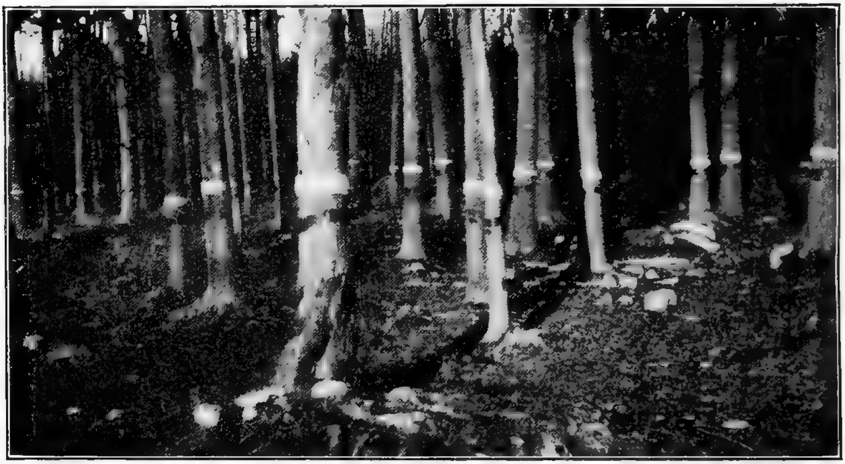


FIG. 11.—Roadside which has been cleared of brush and the trees banded with burlap and tanglefoot. (Original.)

In the spring of 1908 Congress appropriated $250,000 for the work covering the fiscal year from July 1, 1908, to June 30, 1909. The work of clearing roadsides was vigorously pushed throughout the year so that by the spring of 1909, 170 additional miles of 100-foot strips had been put in good condition for summer treatment. In addition to this amount it was necessary to spray and care for 130 miles of strips that had been thinned during the previous years, so that in the summer of 1909 more than 300 miles of roadside were given careful attention, which undoubtedly prevented many new colonies from becoming established. Over 200 miles of roadway, not yet cut out, which was more or less infested, was sprayed, and this served to further decrease the danger of dissemination. (See figs. 13 and 14.)

Late in the summer of 1908 plans were made to carry on an extensive inspection of the outside territory in New Hampshire and Maine. Owing to the size of the territory to be covered in New Hampshire it was divided into two sections, and Mr. Irving L. Bailey was selected to take charge of the western section and Mr. Henry L. McIntyre was placed in charge of the work in the eastern section. Both were men of extended experience in gipsy-moth work in the field, Mr. Bailey having been employed as an inspector when the insect was being fought by the Massachusetts state board of agriculture, and Mr. McIntyre having had much practical experience in town work for controlling the moths and later in the field work which was being carried on by this office.

About November 1, several crews of the most expert men were sent to New Hampshire and from time to time the force was increased until over 100 men were employed in scouting work in the various towns. Practically all of the territory south of Lake Winnepesaukee and a double tier of towns west of the Merrimac River were examined and most of them were found to be more or less infested. In this work all of the roadways, orchards, and private property were inspected; in fact, all trees were examined except the large forest areas. Several crews were detailed to scout along the main highways north of Lake Winnepesaukee, as these form the main routes of travel for summer tourists to the White Mountains. The principal roads from Ossipee to the mountains as far as Bethlehem and Bretton Woods were carefully inspected; also along the roads on the west side of the mountains through the Pemigewasset Valley. No egg clusters were found north of Ossipee on the eastern or above Meredith on the western roads. While this work was being carried on several crews were engaged in making examinations of the territory surrounding the known infested towns in Maine. This region was found to be in much more satisfactory condition than during the previous year. All work that seemed necessary was done in Connecticut and the condition of this territory showed marked improvement.

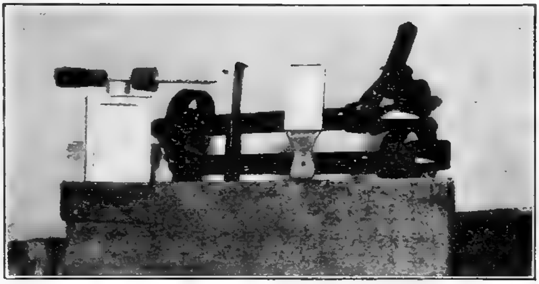


FIG. 12.—Gipsy moth scout's outfit, consisting of climbing irons, mirror, cleaning knife, can of creosote, and brush. (Original.)

The great danger throughout the entire campaign in fighting the gipsy moth has been the existence of large woodland colonies and it has been impossible for either this office, the States, or the individual property owners to keep the moths reduced in territory of this character on account of the vast expense involved. In eastern Massachusetts and southern New Hampshire there are large areas of forest land which are covered with an inferior growth of trees and which are badly infested. In most cases the cost of cleaning up such areas and stamping out the bad colonies would amount to more than the value of the property. This being the case the main attempt has been to keep the roadways through forest areas free from the young caterpillars and to prevent to as great an extent as possible any further spread of the pest. (See Pl. VII.)

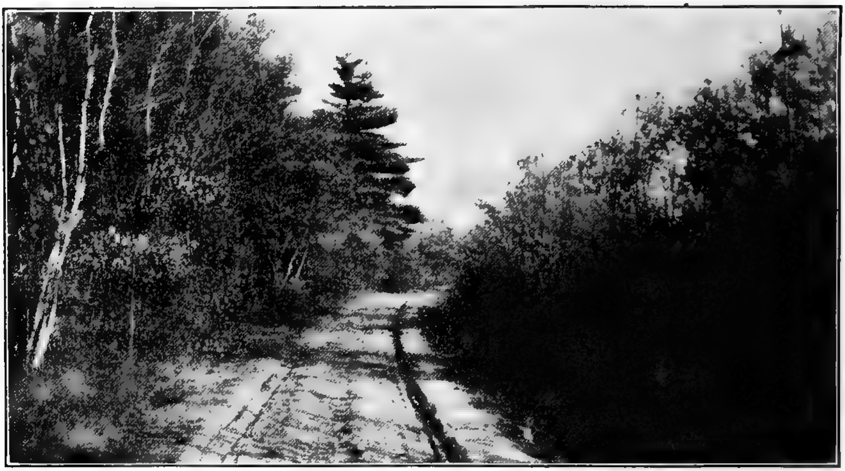
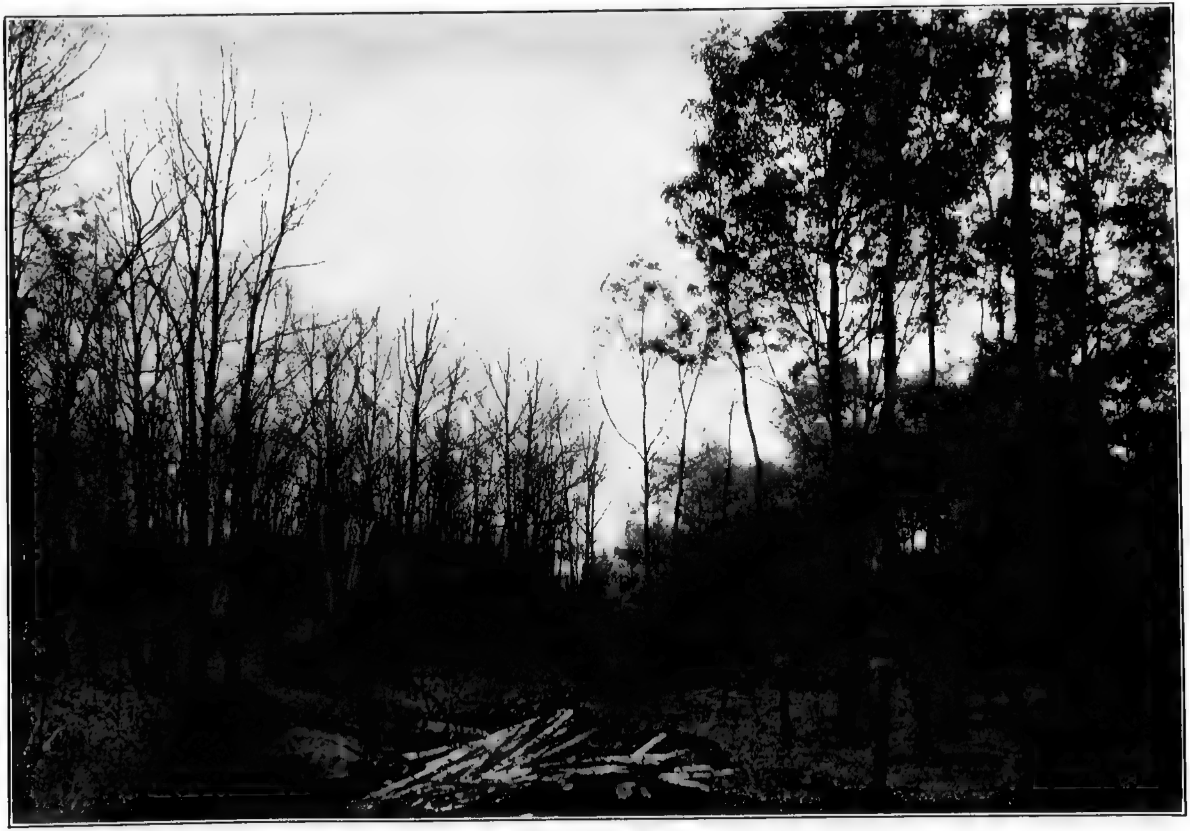


FIG. 13.—Roadsides badly infested by the gipsy moth. (Original.)

During February, 1909, Congress appropriated $300,000 to provide for the continuation of the work. This sum was available for the fiscal year beginning July 1, 1909. Since that time work on roadsides has been continued in Massachusetts and up to January 1, 1910, nearly 150 miles of 100-foot strips have been cut out and prepared for spring and summer treatment.

The roadways cut out up to January 1, 1910, aggregate 450 miles of strips. (See fig. 15.) During the period since the government work began about $300,000 has been expended in Massachusetts for labor and transportation of men. This does not include the amounts expended for salaries, rent, tools, equipment, insecticides, supplies, and the expenses that have been paid by the Government for the maintenance of the Gipsy Moth Parasite Laboratory.

Late in October, 1909, 16 scouting crews of 5 men each were sent to the northern portion of the infested district in New Hampshire



VIEW OF WOODLAND NEAR ROADWAY AT WESTON, MASS., SHOWING EFFECT OF CONTROL MEASURES AGAINST THE GIPSY MOTH. (ORIGINAL.)

[On the right is a strip 100 feet wide in which the gipsy moth has been prevented from destroying the foliage and spreading to the road to be distributed by passing vehicles. The trees on the left have been completely defoliated over an area reaching back nearly a mile into the forest. It was necessary to clear the trees from a strip 25 or 30 feet wide in order to protect the treated zone.]

and since that time 5 more crews have been added, making a total of 21 crews, or 105 men, engaged in examining the towns. The first work was taken up in the region surrounding Lake Winnepesaukee and in towns west of the Merrimac River and north of Concord.

January 1, 1910, 41 towns had been scouted and egg clusters were found in 6 towns not previously known to be infested. No egg clusters were found in 6 other towns outside the infested area, and in 4 towns which were found infested and treated last year a careful examination failed to bring to light any egg clusters.

The severe snowstorm and blizzard which prevailed in New England on December 26 resulted in making the roads almost impassable, and coating the trees with snow and ice, and it was necessary to lay off all the scouting crews until weather conditions were suitable to continue the work.

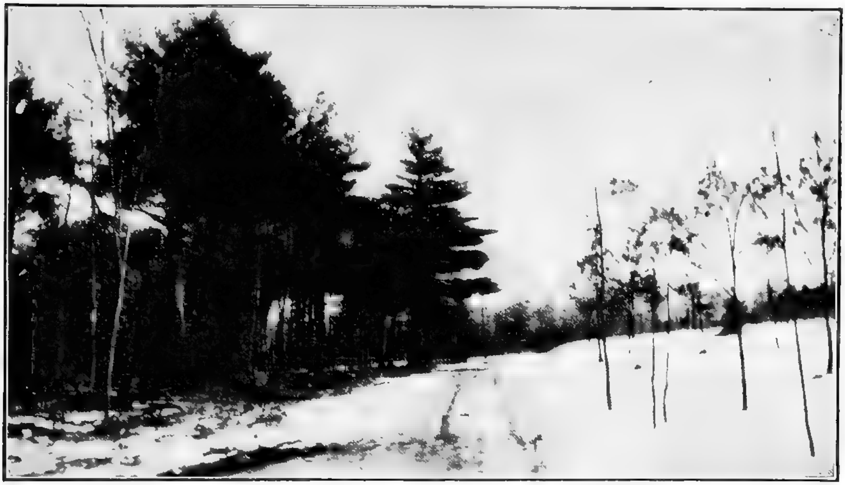


FIG. 14.—Same road shown in figure 13, after the completion of thinning operations against the gipsy moth. (Original.)

During the season when trees are banded with burlap about 47 men working in Maine were carried on the Bureau of Entomology pay roll, and since that time the number has been increased so that about 60 men engaged in cleaning and scouting have been employed. Small colonies have been found in 3 towns not previously known to be infested. In Rhode Island 53 men were employed during July turning burlap, and on November 21 were transferred from the state pay roll and have been engaged in treating egg clusters and cleaning the trees in the infested territory.

Two men in the employ of the Bureau of Entomology examined the colony at Stonington, Conn., in December and only a single egg cluster was found. A large colony of gipsy moths was found at Wallingford, Conn., December 14. It was visited by Mr. Rogers, December 20, and arrangements were made with Dr. W. E. Britton, state entomologist of Connecticut, to cooperate in every possible way to stamp out the pest.

The above is a brief outline of the cooperative work which has been carried on by the Bureau of Entomology in suppressing the gipsy moth.

Winter webs of the brown-tail moth have been destroyed whenever they have been found in the belts which are being cleared along the roadways. This insect has spread so rapidly that it has been impossible to carry on an active campaign against it, and in Maine and New Hampshire only a moderate amount of good would have been accomplished if an attempt had been made to destroy the brown-tail webs along the roadways and in the orchards, as the woodlands, especially in the southern part of these States, are very badly infested. In many towns property owners have destroyed the webs found on their orchard and shade trees.

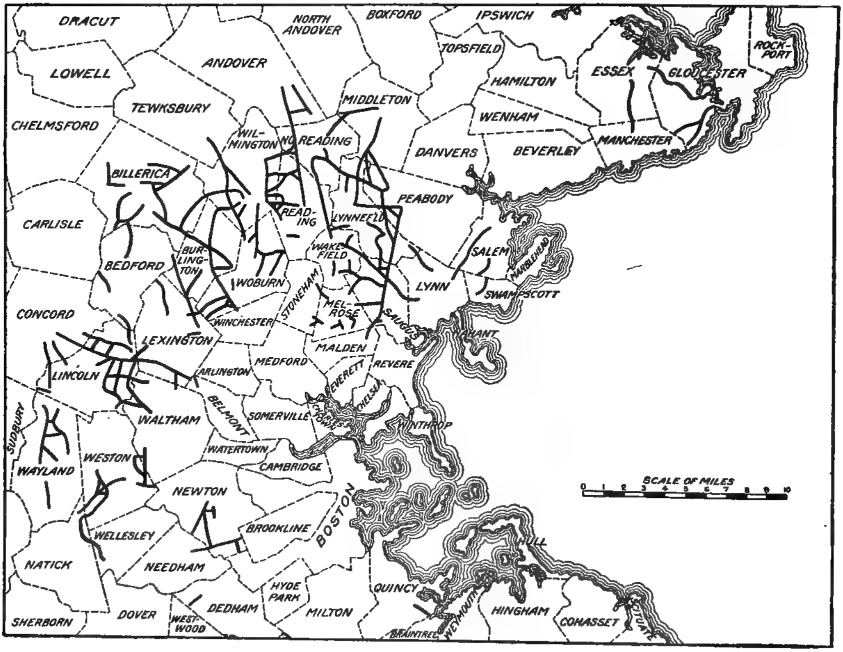


FIG. 15.—Map showing roads in Massachusetts where the brush has been cut, the trees thinned, and those remaining treated by employees of the Bureau of Entomology to prevent the spread of gipsy-moth larvæ on vehicles. (Original.)

The work of suppressing the gipsy moth is carried on in a different way in each of the New England States. In Massachusetts a large annual appropriation is made by the State, and property owners as well as towns and cities are required to assist in the control of the insect.

The work of the Bureau of Entomology in Massachusetts, therefore, has been practically independent of the state work, except that a hearty spirit of cooperation has always existed between the two offices. In Maine the state appropriations have not been sufficient to finance an active campaign against the insect throughout the year, and a system of cooperation has been established between this office and the Maine department of agriculture, so that the work can be continued uninterruptedly. In New Hampshire, owing to the small appropriations made by the State, the greater part of the work has been carried on by the Bureau of Entomology, the state funds being used for urgent calls which it was impossible for this office to attend to. Practically the same conditions hold in Rhode Island as in Maine, while in Connecticut most of the work has been carried on by the State, and the Bureau of Entomology has furnished only such assistance as was deemed necessary to supplement the local work at Stonington and Wallingford. A summary of the work done in the New England States is given herewith.

WORK BY THE STATE OF MASSACHUSETTS.

During the past five years the State of Massachusetts has appropriated $1,195,000 for the purpose of controlling the gipsy and brown-tail moths, and an additional sum of $75,000 has been expended in an attempt to introduce their parasites and natural enemies. The money has been used, in the main, in reimbursing cities and towns in the infested parts of the State which have expended more than was required by the gipsy moth law. A small part of the appropriation has of course been used for maintenance and supervision of the work, and the central office has adopted a system of inspection of the city and town work in order that uniform standards might be enforced and useless expenditures prevented. The men employed as agents and inspectors by the central office have had long experience in fighting these pests, many of them having served when the work was under the direction of the state board of agriculture.

The amount of money expended by the different cities and towns affected has about equaled that appropriated by the State, while many private property owners and state commissions (such as the Metropolitan Water and Sewage Board and the Metropolitan Park and State Highway Commissions) have expended large sums of money, so that the amount expended annually, exclusive of that spent by the Federal Government, has averaged about $750,000 to $800,000.

The result of the work has been to reduce greatly the infestation in the residential sections. This has not been accomplished, however, without vigorous application of all the best-known methods of fighting the pests. Spraying has been carried on in a wholesale way, and at the present time most of the infested towns have purchased high-power sprayers, so that a large area of territory can be covered in the short time that the insect is in the larval stage.

In 1909 over 150 high-power and 250 hand spraying outfits were used in the infested district in Massachusetts.

Unfortunately many of the less valuable woodland sections have received little attention, owing to the pressure of more important work. This results each year in large areas being stripped by the caterpillars, great numbers of which die from starvation and disease, and in this way the infestation for the next year or so is materially decreased. Fortunately these badly infested areas are more or less isolated, as strong effort is made to care for the woodland section that is near roads or lines of travel, so that the danger of spread of the insects from these centers of infestation is reduced as much as possible.

It has been impossible, however, up to the present time, owing to the excessive cost, to do all of such work that could be done to advantage. As the residential areas become freer from the insects more funds can doubtless be devoted to this much-needed work.

In addition to the work already outlined a large amount of scouting has been carried on under the direction of the central office and at state expense. This has been done by skilled and experienced men in the towns outside the known infested territory. All the main roads and orchards have been examined in a section several towns deep around the infested area.

Some of the more important and much traveled state roads have been scouted for long distances and this work in 1907 and 1908 resulted in the discovery, near Springfield and Greenfield, Mass., of small colonies of the gipsy moth.

The infestation near Springfield was located near the state road, which is a favorite route for automobiles between Boston and New York City. The outlying colonies discovered in this way have been treated with special care and many of them have been reduced almost to the point of extermination.

The area infested at the present time in Massachusetts is somewhat larger than that which was found in 1905 when the first scouting operations were begun after the work was resumed by the State. This is what would naturally be expected, as it was at that time impossible to undertake scouting operations over such a large territory with the small force of trained men available.

Doubtless many of the colonies since found developed from caterpillars scattered during the time the moth was allowed to spread without restriction, and more colonies will probably be found in the outside territory. Further scouting should be taken up so that these may be discovered at the earliest possible moment and promptly treated.

Much credit is due to the State of Massachusetts for the energetic manner with which this campaign has been waged. The officials at the state office, under the direction of Mr. Kirkland, and later under Mr. L. H. Worthley and State Forester Rane (in whose charge the work was placed by the last legislature), have accomplished excellent results in spite of the many difficulties which had to be met and overcome.

The work undertaken in Beverly, Manchester-by-the-Sea, Gloucester, and Rockport—the region which is known as the north shore of Massachusetts Bay—and also in the towns of Hamilton, Wenham, and Essex deserves special mention. The value of the woodland in this section is probably greater than any other area of the same size in New England, and this fact, together with the magnificent ocean scenery, has resulted in these towns becoming the summer residences of many prominent citizens from all parts of the country. The gipsy moth threatens the destruction of these valuable forests, and as the land is of little agricultural value the towns concerned would shrink thousands of dollars in valuation, and much of the territory would be uninhabitable during the summer season, thus working a double loss to the sections of the State concerned. During the past two years a special fund for carrying on the work has been furnished on the basis of the State supplying one-third, the city of Beverly and the town of Manchester one-third, and the balance being subscribed by the summer residents. In 1909 over $60,000 was expended, the work being carried on by the state forester's office. Over 2,100 acres of woodland have been thinned, sprayed, and protected from moth injury.

Col. Wm. D. Sohier, chairman of the citizens' committee which raised private funds for carrying on the work, in a report recently issued, says:

> It is perfectly evident that had it not been for the work which was done last year and this year conditions on the north shore from Beverly all the way down through Manchester would have been unbearable. All the trees would have been stripped except on a few private estates, and all the pines and hemlocks would have been killed.

Many improvements in methods have been developed while the work has been in progress. Most of these resulted from suggestions made by different members of the state and government forces. A large number of ideas have been tried out in the field to test their utility, and a considerable number of these have been made cooperatively between the state and governmental offices. The whole effort has been to secure the best results by adopting the cheapest possible methods, and practical suggestions have been received with alacrity.

WORK IN THE STATE OF MAINE.

Webs of the brown-tail moth were found at Kittery, Me., in the spring of 1904 by one of the deputy state nursery inspectors of New Hampshire, and Prof. C. M. Weed, who was then entomologist of the New Hampshire agricultural experiment station, informed Hon. A. W. Gilman, commissioner of agriculture of Maine, of the presence of this insect in the latter State. An examination was made at Kittery and in the vicinity by Miss Edith M. Patch, entomologist of the Maine agricultural experiment station, and through the efforts of the above-named officials considerable work was done in the fall of 1904. Many winter webs were collected and burned. Infestations were found not only in Kittery, but at York, Eliot, and other points to the eastward along the coast. Owing to the large territory over which this insect was spread the matter was brought to the attention of the legislature the following winter and an act passed appropriating $5,000 for the year 1905, and $5,000 for the year 1906, for the purpose of controlling the pest. The office of state entomologist was created and placed under the direction of the state commissioner of agriculture, and Prof. E. F. Hitchings, of Waterville, Me., was appointed to take charge of the work. Many of the towns in the infested section voluntarily raised funds to fight the pest, so that a considerable amount in addition to the state appropriation was available for expenditure during the years mentioned.

Owing to the danger of the State becoming infested with the gipsy moth, an appeal for a national appropriation was urged by the State of Maine, in connection with other New England States, and in the fall of 1906 it was possible for this office to send several scouting parties into the section of Maine nearest the infested area in New Hampshire. As a result of this inspection, egg clusters of the gipsy moth were found at Kittery, Eliot, York, South Berwick, Wells, Kennebunk, and Kennebunkport. Several men examined the principal cities and towns east of Portland, but no infestation was found except a single egg cluster discovered by these men on the grounds of the National Soldiers' Home at Togus, Me., which was 81 miles from the nearest known infested locality. Doubtless this infestation was brought about by inmates or visitors unintentionally conveying some of the insects from the infested territory on their clothing or among their personal effects. The work during the year 1906 was continued in Maine with great vigor. The towns found infested showed a generous spirit of cooperation in fighting not only the gipsy moth but the brown-tail moth. The Old York Transcript, in its issue of January 18, 1907, stated that 120,000 brown-tail webs (fig. 16) were burned in a single day. Most of the money expended for collecting these webs was raised by private subscription or appropriated by the towns involved. In spite of the vigorous work carried on in the brown-tail moth infested section, the insect continued to spread with marked rapidity and was found in many towns east of the known infested area. In the fall of 1907 scouting parties examined the roadways and orchards throughout the gipsy-moth infested territory. This resulted, as might be expected, in the discovery of several vigorous woodland colonies in Kittery and York. Work was immediately begun in clearing out the brush and sprout growth in the infested region, creosoting the egg clusters, and preparing for effective summer treatment. Five new towns were found infested with the gipsy moth as a result of scouting work during the winter of 1907–8, namely, Berwick, North Berwick, Sanford, Lebanon, and Acton.

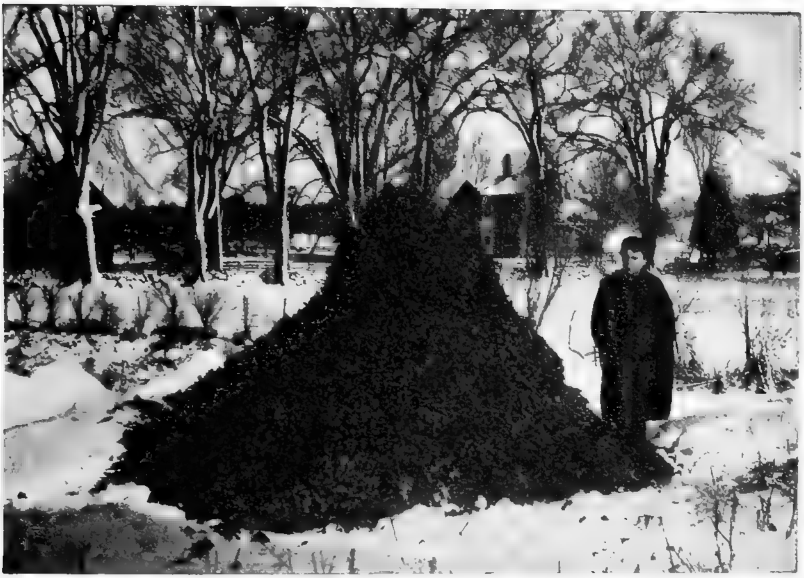


FIG. 16.—Pile of 120,000 webs of the brown-tail moth gathered and destroyed at York, Me. (From Hitchings.)

The following summer the infested areas were burlapped and given careful attention, especially the one at Togus, where an attempt was made by the Maine department of agriculture to secure the extermination of the insect. The work at this point was especially difficult, owing to the large number of people who visited the home during the spring and summer, and because it was not possible to remove some of the board walks, which furnished excellent places for the moths to deposit egg clusters. The trees surrounding the one infested were burlapped and tended during the summer, and in the fall the grounds were thoroughly scouted for egg clusters. In addition to the caterpillars, pupæ, and moths found when the burlap bands were turned, 40 egg clusters were found and treated.

As a result of the thorough work done only a few caterpillars and no egg clusters were found in the summer of 1908, and although the same methods have been employed as in previous years none of the insects was found in 1909. The last specimen taken was a caterpillar, July 11, 1908. It is probable that this colony has been completely exterminated, although the location and character of the place render it peculiarly liable to future infestation. Since the year 1907 the gipsy moth state work has been under the general oversight of Capt. E. E. Philbrook, and the state force has worked in close cooperation with the government office. The work has been especially difficult, owing to the necessity for training new men, and also because the country along the Maine coast, which is infested, is rough and broken and furnishes opportunity for egg clusters to be hidden in situations where it is almost impossible to find and destroy them. During the winter of 1908–9 scouting work was continued, and small infestations were found in Newfield, Waterboro, Biddeford, Saco, and Scarboro. All the known colonies in Maine have been given most thorough attention, and their condition has improved each year. An important feature of the work has consisted in sending out scouting parties to examine the roadways, orchards, and places likely to be infested outside of the known infested area. This has been done in a limited way, but more work of this character must be taken up in order to determine positively the extent of the infestation. During the fall of 1909 the scouting work was pushed vigorously, not only along the roadways and in the orchards, but crews of trained men were sent into the woodland area to make thorough inspections. Three towns, namely Shapleigh, Gorham, and Dayton, have been found slightly infested, and during the progress of the work a large woodland colony was found in the Agamenticus district in the town of York. The location of this colony is in a region seldom frequented and practically inaccessible to travel. Scouting is being continued for the purpose of discovering any similar colonies that have not yet been found.

The work in Maine has been carefully and thoroughly prosecuted, and the state officials have shown much interest and enthusiasm in meeting this difficult problem. A force of men has been organized and trained to a high degree of efficiency. During the time the work has been in progress it has met with the hearty approval and cooperation of citizens in the infested district. As an example of the esteem in which the work is held it may be stated that during the past year the summer residents and public-spirited citizens of York contributed $1,000 and purchased a power spraying machine, which was turned over to the Maine department of agriculture for treating infested areas.

The amount appropriated by the State from 1905 to January 1, 1910, has been $95,000, and $50,000 additional has been used by the Bureau of Entomology in the moth work in Maine.

WORK IN THE STATE OF NEW HAMPSHIRE.

The first infestation of the gipsy moth in New Hampshire was discovered in 1905 by inspectors from the Massachusetts state office, loaned by agreement between Mr. Kirkland and the New Hampshire experiment station. Three experienced men were detailed and the experiment station sent Mr. W. P. Flint, an assistant in the entomological department, to make an examination of the trees along the roads in the coast towns from Seabrook to Portsmouth. Egg clusters were found in these towns and also in Hampton Falls, Hampton, North Hampton, Rye, and Greenland. Additional scouting was done in Exeter and Nashua, but no evidence of the moth found.

The brown-tail moth had already thoroughly established itself in southern New Hampshire and was causing great injury to orchard, shade, and forest trees.

No state funds were available for moth work. In 1906 a request was made for assistance from this office, soon after the first appropriation was available, but it was too late to do any effective work against the caterpillars, and as no serious outbreak of the pest was evident, scouting was deferred until winter, when an examination showed that the gipsy moth was present in 36 municipalities in the southeastern part of the State.

At the 1907 session of the legislature a law embodying some of the principal features of the Massachusetts law was enacted, and $12,500 appropriated for each of the years 1907 and 1908. The enforcement of the law was placed in the hands of the governor and council with authority to appoint a state agent, if it was deemed necessary. During the first year the burlap work was let out by contract, and Mr. G. E. Merrill, of Hampton Falls, N. H., was employed to inspect the work of the contractors.

All trees within about 100 feet of infested trees in the towns east of Pelham along the Massachusetts border, and the coast towns to Portsmouth, were burlapped and tended, and although some benefit resulted, the amount of money available was entirely inadequate to accomplish satisfactory results. At the close of the year Col. Thomas H. Dearborn, of Dover, was appointed state agent, and has since that time had charge of the moth work.

The appropriations made by the State have not been increased, although the scouting operations of the Bureau of Entomology have resulted in the discovery of the gipsy moth in more than 100 cities and towns. All of Rockingham, Strafford, and Belknap, most of Hillsboro and Merrimack counties, and a few towns in Carroll County are infested—an area of about 3,000 square miles. All the roadsides and orchards in this entire territory have been examined, and similar work has been done in a tier of towns surrounding the infested region, in an attempt to determine the extent of the infestation and to prevent the spread of the pests from colonies along the highways. For three years the greater part of this territory has been inspected in a similar manner.

During the summer thousands of people from all sections of the country visit the State, which is noted for its summer resorts and mountain scenery, and this has been a potent factor in dispersing this insect. Many automobile parties tour the State, and not infrequently trips are made from Boston and vicinity to the White Mountains and lake resorts. During the time the gipsy moth was allowed to develop without interference in Massachusetts, excellent facilities were offered for its dispersion throughout New Hampshire. Travel is unusually heavy at the opening of the vacation season, which is the time when the larvæ are small and most easily carried.

The scouting operations have resulted in locating many colonies in and around summer camps and country houses frequented by vacationists who come from badly infested districts in Massachusetts.

The most serious feature of the problem in New Hampshire is the undoubted infestation of a large part of the thickly wooded area in the southern part of the State. Remedial measures are entirely impracticable, as it is impossible to apply them to such large areas of low-priced forests, owing to the great expense involved.

The greater part of the area is not yet badly infested, but unless the people of the State become aroused and exert themselves to check the gipsy moth serious injury will be caused to the trees and enormous loss is bound to result.

In the residential sections the people will, when the moth increases to an extent to cause serious injury, undoubtedly awake to the situation, and exert themselves to preserve their trees.

The brown-tail moth has been found in an area covering over one-half of the State, and in the entire section east of the Connecticut River watershed and south of Lake Winnepesaukee it is most abundant and is causing great damage. Its presence has caused much complaint from residents and summer visitors, and this has led to effective work being done along the roadways and in some of the towns. Colonel Dearborn has succeeded in awakening considerable interest in this work in certain sections of the State, and some relief from this troublesome pest has been secured where it has been possible to sufficiently arouse public sentiment.

The State has spent $37,500 and the Bureau of Entomology about $90,000 in the work in New Hampshire.

WORK IN THE STATE OF RHODE ISLAND.

The presence of the gipsy moth in Providence was discovered in 1901, and some effort was made by the city and property owners to destroy the insect during the following two years. In 1906, the year after the state work was begun in Massachusetts, a law was enacted in Rhode Island providing for control measures against the gipsy moth. An appropriation of $5,100 was made. This was inadequate for the work, but by means of a cooperative arrangement between the state superintendent, Prof. A. E. Stene, and the Bureau of Entomology it was possible to carry on a vigorous campaign. The original infestation was confined almost entirely to residential property, and at the present time very little woodland in the State of Rhode Island is known to be infested.

Infestations have been found in 11 towns in the northeastern part of the State, extending from the Massachusetts line and including one tier of towns west of the city of Providence. The work which has been done has resulted in the extermination of a large number of small colonies, and those localities in which the moth is now present are of limited extent and are being given careful attention. In many cases the caterpillars or egg clusters were found in brush and undergrowth growing on dumps or unimproved building lots and much work has been required to clean up infestations of this character.

Since the work began practically all of the State has been scouted except the towns north of Westerly along the Connecticut line.

In 1907, $10,000, in 1908, $10,000, and in 1909, $8,000, was appropriated for moth work, and with the help which has been furnished by the Bureau of Entomology great progress has been made. Each year all the trees in the infested area have been carefully examined and fences, buildings, and shrubbery thoroughly inspected for egg clusters. In order to check up the work two experts have gone over the territory after the regular workmen in order to ascertain if any egg clusters had been missed.

During the summer of 1909 about 150,000 trees were burlapped in Providence and surrounding towns. These were visited twice a week during the caterpillar season, and all the insects found were crushed by the workmen. The cavities in a large number of trees in the infested section have been filled with cement or covered with zinc so that work can be more thoroughly done. In order to show the progress which has been made in Rhode Island, it should be stated that during the winter of 1906–7 nearly 80,000 egg clusters were found and destroyed. During the following winter, 1907–8, only 7,500 egg clusters could be found, and in the winter 1908–9 but 1,700 were discovered and treated. It is believed that the moth has been exterminated in 4 of the 11 towns which were infested. The entire territory in this State is in excellent condition, and very little injury now results to the trees, as the insect is present only in small numbers. With persistent work for a number of years it should be possible totally to exterminate the insect in this State, but this can not be accomplished and the region kept free from infestation unless the vigorous work which is now being carried on in the other New England States is maintained. Throughout the period that the work has been in progress in Rhode Island most cordial relations have existed between the state superintendent and this office, and this is one of the factors which has made the work so successful.

The amount appropriated by the State during the four years the work has been in progress is $33,100. In addition to this the National Government has expended about $28,000.

WORK IN THE STATE OF CONNECTICUT.

Adult specimens of the gipsy moth were found by Mr. Ernest Frensch, a local collector of insects, at Stonington, Conn., near the Rhode Island state line during the summer of 1905. He reported the matter early in the year 1906 to Dr. W. E. Britton, state entomologist of Connecticut, who at once made an investigation and found that the report was correct. An emergency fund was available in that State, and was placed at the disposal of the state entomologist for the purpose of stamping out the pest.

The work has been managed in a very efficient manner, and each year such assistance as was desired has been furnished by the Bureau of Entomology. The original infestation covered practically 1 square mile, this having been determined by very careful scouting operations. This colony has been very difficult to treat successfully owing to the broken and rocky character of the ground and to a large number of pastures and brush-covered areas which furnished excellent places in which the eggs of the moth could be deposited. In the autumn of 1906 a determined effort was made by the state entomologist to exterminate the moth in this town, and all brush was cut in the woodland and pastures throughout the infested area. The following summer the trees were burlapped after having been previously pruned and all cavities sealed with cement or patched with zinc. Many stone walls were burned out with a cyclone burner, some spraying was done during the caterpillar season, and a number of trees were banded with tanglefoot. Working on the theory that colonies originated from the introduction of caterpillars by some peddler or milkman or other person making frequent visits over quite a large area, several of the adjoining towns were scouted to determine if other colonies existed from which these caterpillars might have been distributed. No evidence was found, however, of outside colonies. During the summer of 1906 approximately 10,000 caterpillars were destroyed, and during the winter of 1906–7, 118 egg clusters were treated with creosote. By following up the methods already outlined the infestation has decreased each year, and during the summer of 1909 less than 100 caterpillars were killed. The final inspection recently completed revealed the presence of only 1 egg cluster. The condition of this colony in Connecticut is very satisfactory and much credit is due the state entomologist and his assistants for the efficient work which has been done. A small amount of help has been furnished by the Bureau of Entomology when it was desired, and it is evident that extermination can be accomplished by following up the work in a thorough manner, although the territory is a most difficult one to treat.

On December 14, 1909, a letter was received from Dr. W. E. Britton stating that a colony of the gipsy moth had been found in the town of Wallingford, about 12 miles north of New Haven. Several men were immediately sent by him to investigate the matter thoroughly, to determine the amount of territory infested, and to treat egg clusters. On December 20, Mr. Rogers and Doctor Britton visited Wallingford and saw many badly infested trees near the center of the town. The examination which had been carried on previous to that time showed that the moth had spread over approximately one-half of the borough. The principal infestation was located in the rear of a grocery store, and during the caterpillar season delivery wagons and other vehicles must have furnished excellent opportunity for the spread of the insects. Undoubtedly, a considerable area will be found infested after a thorough examination has been made. It is probable that this colony has existed for at least three years, and possibly for a longer time. The total number of egg clusters treated up to January 1, 1910, aggregated over 5,000.

The presence of this bad colony, which is at least 100 miles from the badly infested area in Massachusetts, indicates the probability that other colonies may exist at equally distant points. From the fact that the center of the infestation appears to be near the provision store mentioned, and also because lettuce, cucumbers, and other garden crops were undoubtedly shipped to this point from market gardens near Boston, it is possible that the infestation may have been caused by egg clusters brought in boxes used for transporting these products. If this supposition is correct, it is probable that many points outside the infested district in Massachusetts became infested in this way during the years when no work was done in that State. Every effort will be made to stamp out the pest in Wallingford, and arrangements are on foot to place a sufficient number of men in the town to thoroughly inspect and treat the infested area, and to examine carefully the surrounding territory.

INSPECTION OF LUMBER AND FOREST PRODUCTS.

On March 27, 1909, a letter was received from Mr. A. M. G. Soule, one of the foremen in charge of the scouting work in Maine, which stated that while examining woodland along the railroad near Scarboro Beach, Me., he found a quantity of oak shim wood, which was being used by the section men in repairing the track, badly infested with gipsy moth egg clusters.

An investigation showed that the wood was originally shipped from a badly infested district near Bedford, Mass., and that it had been delivered at various section houses along the railroad between South Lawrence, Mass., and Portland, Me. By following up the deliveries, infested wood from this shipment was found at Kennebunk, Biddeford, Pine Point, and Scarboro Beach, Me. The entire shipment, so far as could be determined, was traced and the egg clusters treated wherever they were found. This discovery emphasized the danger of shipping forest products of all kinds by rail after the egg clusters of the gipsy moth had been laid, and arrangements were at once made to inaugurate a system of inspection by means of which distribution of egg clusters from the infested area to distant points could be prevented. The matter was presented to the Chief of the Bureau of Entomology, and later a letter was sent by the Secretary of Agriculture to the different railroad companies operating in the infested district, requesting their cooperation with the Bureau of Entomology in preventing further spread of this insect. The officials of the several railroads operating within the infested district gave assurance of their interest in the matter, and promised all possible assistance in confining the pest to the present territory. Orders were issued by the railroads to all station agents within this area that after July 1, 1909, forest products would be accepted for shipment only when accompanied by permits or certificates of inspection from this office. As soon as shippers became acquainted with the requirements little delay was experienced, and the order has met with hearty approval and a generous spirit of cooperation. When such material is being forwarded from one town in the infested district to another known infested point, a permit to ship is granted after proper application has been made. The inspection of such shipments is not attempted unless there is special danger of transmitting infested material. On shipments, however, that are destined to points outside the infested territory, inspection is made by employees of this office before a certificate is granted allowing shipments to move. As a result of this work, inspections have been made of 490 shipments, many of which were badly infested. The following table gives the geographical range of the shipments sent out from infested territory from July 1, 1909, to January 1, 1910. Each shipment averaged about a carload lot, although in some cases as high as 10 carloads were examined for a single shipment. Over 1,000 cars of forest products have been shipped from the infested district in Maine during this period. Practically all the lumber region in this State is outside the infested area.

This material consisted chiefly of railroad ties, posts, poles, cord wood, bark, staves, rough lumber, and, in the last few weeks of 1909, small evergreen trees for the Christmas trade. The enforcement of the inspection requirements has resulted in a large amount of additional work for this office, but as several badly infested shipments have been prevented, the expense of the work has been amply justified. A large shipment of lumber consigned to Holyoke, Mass., was found badly infested, and held until it could be thoroughly inspected and treated before it was allowed on the cars. Lumber which was destined to Philadelphia, Pa., and other points as far removed from the infested region was also held up for thorough inspection and certification. This has been the means of preventing a number of colonies from gaining a foothold in States outside of New England.

Number and geographical distribution of lumber shipments forwarded to uninfested points.

CONNECTICUT.

Ansonia, 4.
Bridgeport, 11.
Danbury, 2.
Derby, 2.
Greenwich, 1.
Hartford, 7.
Litchfield, 1.
Lyme, 1.
Meriden, 3.
New Haven, 13.
New London, 2.
Norwich, 2.
Seymour, 6.
Torrington, 2.
Waterbury, 5.

ILLINOIS.

Chicago, 1.

MAINE.

Auburn, 1.
Buxton, 2.
Freyeburg, 2.
Millinocket, 2.
Portland, 35.
Westbrook, 4.

MASSACHUSETTS.

Acushnet, 1.
Amherst, 1.

MASSACHUSETTS—cont'd.

Athol, 3.
Barre, 2.
Fair Haven, 1.
Fall River, 7.
Holyoke, 25.
New Bedford, 4.
Northampton, 1.
Royalston, 1.
Shelburne, 1.
Southbridge, 2.
Springfield, 2.
Ware, 2.
Winchendon, 2.

NEW HAMPSHIRE.

Berlin, 1.
Campton, 1.
Canaan, 2.
Claremont, 1.
Conway, 1.
Gorham, 1.
Greenfield, 4.
Hancock, 2.
Harrisville, 6.
Haverhill, 4.
Keene, 10.
Lisbon, 1.
Madison, 2.
Marlboro, 3.
Newport, 2.

NEW HAMPSHIRE—cont'd.

Peterboro, 9.
Plymouth, 1.
Rumney, 1.
Swanzey, 1.
Winchester, 1.

NEW JERSEY.

Camden, 2.
Edgewater, 1.
Edgeworth, 1.
Helmetta, 1.
Hoboken, 1.
Irvington, 1.
Jersey City, 2.
Keyport, 1.
Newark, 3.
New Brunswick, 2.
Passaic, 3.
Paterson, 1.

NEW YORK.

Albany, 1.
Arden, 1.
Brooklyn, 1.
Claremont Park, 1.
Cornwall, 2.
Dunkirk, 2.
Hornell, 1.
Ilion, 1.
Kingston, 1.

NEW YORK—continued.

Long Island City, 2.
Morris Heights, 1.
Mount Kisco, 1.
New Hartford, 2.
New Rochelle, 1.
New York City, 7.
Oneida, 1.
Peekskill, 1.
Port Chester, 1.
St. Johnsville, 1.
Seacliff, 1.
White Plains, 2.

OHIO.

Sandusky, 5.

PENNSYLVANIA.

Allentown, 1.
Pen Argyl, 1.
Philadelphia, 18.

RHODE ISLAND.

Bristol, 2.
Coventry, 2.
Newport, 2.
Woonsocket, 2.

VERMONT.

Barton, 4.
Bellows Falls, 1.
Brattleboro, 1.
Lyndon, 1.
St. Johnsbury, 1.

DISTRICT OF COLUMBIA.

Washington, 2.

Aside from the certificates required for shipping forest products outside the infested territory, a large number of permits, aggregating 2,624 to January 1, 1910, have been issued allowing the transportation of these products inside the infested district.[a]

This inspection feature of the work is of great importance and must be well organized and thoroughly enforced if the gipsy moth is to be prevented from becoming established at distant points. This is especially true, since at the present time large forest areas are heavily infested, and in order to harvest the marketable lumber many owners are cutting and shipping. Where large cutting operations are carried on it is customary to use portable sawmills, and the rough lumber is often piled in the woodland where it may remain one or two seasons. This may result in the lumber becoming badly infested with egg clusters. (See Pl. VIII.) A number of cases have been found which indicate that the moth has been spread by the removal of these portable sawmills from one infested area to another where no infestation existed.

The report has recently been received that gipsy moth egg clusters were found in Providence, R. I., on boxes which had been used by market gardeners in shipping their produce. This feature concerning the spread of the moth is very difficult to regulate, and about the only measure seems to be the requiring of shippers of such produce to keep their grounds and premises free from the pest. The thorough inspection and cleaning up of such premises will undoubtedly result in checking the spread of the insect in this way.

DANGER OF INTRODUCING THE GIPSY MOTH AND BROWN-TAIL MOTH FROM FOREIGN COUNTRIES.

The suppression and inspection work which is being carried on in New England of course can not prevent the introduction of these

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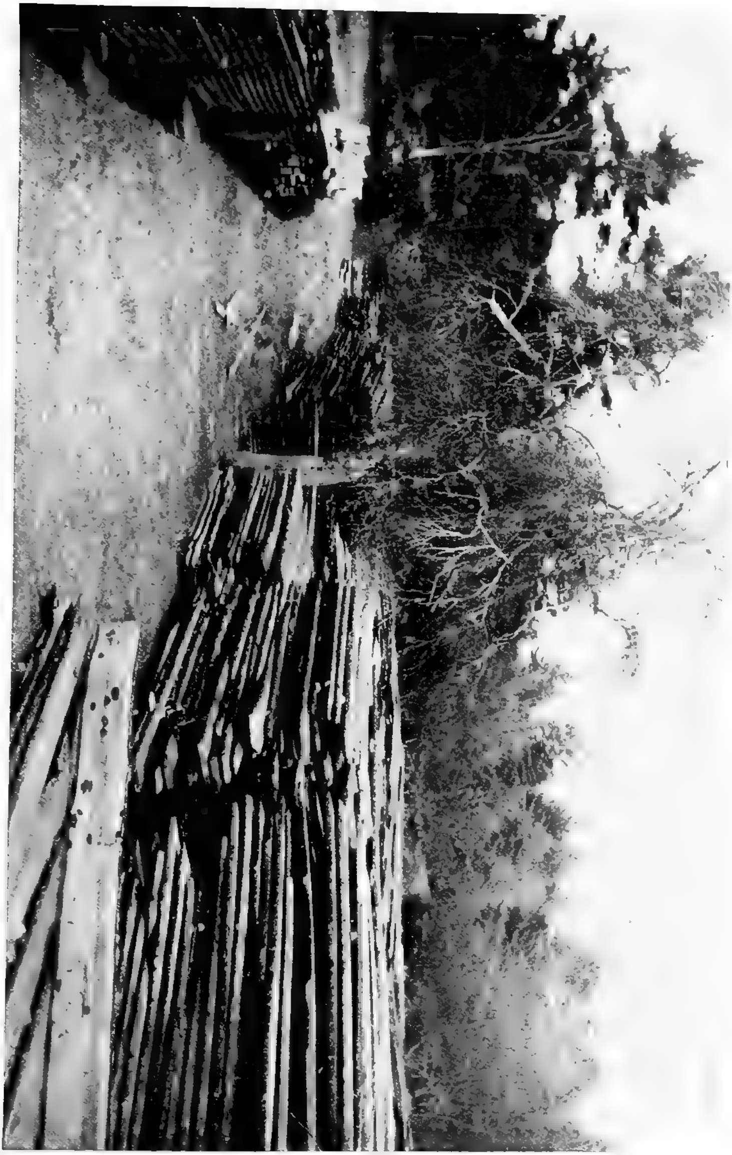
[a] From January 1, 1910, to May 25, 1910, 227 certificates and 102 permits were issued. Several infested shipments were found, which were carefully treated before being released. In addition to the New England States these shipments were sent to New York, Pennsylvania, Delaware, Virginia, and Ohio.



LUMBER PILES AT YORK, ME., INFESTED WITH EGG CLUSTERS OF THE GIPSY MOTH.

pests from foreign countries, and unfortunately at the present time there is no effective general law which provides for the inspection of nursery stock or other products, coming into the country, on which these insects are likely to be transported. Most of the States have nursery inspection laws which are enforced with special reference to preventing the introduction and spread within the State of the San Jose scale and other dangerously injurious insect pests. Most of these laws are well enforced, and the officials in charge have been provided with sufficient funds to carry on the work. The ports of entry, which are controlled by the United States Government, have not come under the jurisdiction of the State officials, and when inspections were made of stock coming to the United States from foreign countries, they have been carried on at the point of destination. Little attention was given to this feature of nursery inspection work until during the winter of 1909 discovery was made by the inspectors working under the direction of the commissioner of agriculture of New York that seedling nursery stock imported from France was being received at various nurseries in the State, which in many cases bore webs containing hibernating caterpillars of the brown-tail moth. This matter was given immediate attention, and the inspectors in the different States were cautioned, both by the commissioner of agriculture of New York and the Chief of the Bureau of Entomology at Washington, to be on the lookout for such stock. As a result of this warning and of the arrangements made by the Bureau of Entomology with the custom-house officials, notice was sent to inspectors in all of the States of the arrival of any nursery stock shipments in this country, so that an inspection could be made as soon as the stock reached its destination. Most of the States followed up the shipments energetically, and carefully inspected them, but in a few where no funds were available for doing the work the local inspector was deputized by the Bureau of Entomology to examine the importations and the work was paid for out of the appropriation for preventing the spread of moths which had been made for carrying out the campaign in New England.

At the close of the season it was found that brown-tail moths had been found in shipments of stock that had been received in 15 different States, viz, Alabama, Georgia, Illinois, Iowa, Kansas, Kentucky, Maryland, Massachusetts, Missouri, Nebraska, New Jersey, New York, North Carolina, Ohio, and Pennsylvania. In New York State alone over 7,000 webs were found and destroyed. A single egg cluster of the gipsy moth was found in a shipment received in Ohio.

A bill (H. R. 23252, 61st Congress, 2d Session) "To provide for the introduction of foreign nursery stock by permit only, and to authorize the Secretary of Agriculture to establish a quarantine against the importation and against the transportation in interstate commerce of diseased nursery stock or nursery stock infested with injurious insects, and making an appropriation to carry the same into effect" is now under consideration by the Committee on Agriculture of the House of Representatives and it is earnestly hoped that it may receive favorable action. The urgent need of some legislation of this character should be apparent to any person who has given the matter serious thought. From a financial point of view it is much easier and cheaper to stamp out a few insects before they have had an opportunity to gain a foothold in this country than to attempt to exterminate or suppress them after they have had a chance to multiply and become acclimated.

EXPERIMENTAL WORK IN THE CONTROL OF THE GIPSY AND BROWN-TAIL MOTHS.

During the progress of the field work on the gipsy and brown-tail moths it has been necessary to carry on a limited number of experiments and to make investigations so that more economical methods could be used in destroying these insects. It has been known for years that a single defoliation will cause the death of pine or other coniferous trees and some of the men engaged in the field work reported that small caterpillars of the gipsy moth did not appear to feed on the foliage of these trees. In 1907 Mr. F. H. Mosher, one of the entomologists connected with the Massachusetts work, carried on an extensive series of experiments in feeding newly hatched gipsy-moth caterpillars on pine foliage. The results secured showed that the caterpillars would starve rather than eat the food offered, and as a result of this test it became evident that it was necessary for the small caterpillars to have a considerable amount of deciduous food before they were able to attack pine. Using these experiments as a basis, an extensive field test was made in the spring of 1908 by the Bureau of Entomology in cooperation with the Massachusetts state office.

An area of about 5 acres of pine woodland located in Arlington, Mass., was selected for the test. The woodland was surrounded by farm land upon which were growing many fruit and shade trees, as well as a considerable amount of brush and undergrowth, all of which was very badly infested with the gipsy moth. The pine trees were banded with tanglefoot early in the spring and no other treatment was applied except combing the bands. These trees, as well as the deciduous trees on the surrounding ground, were badly infested with egg clusters of the gipsy moth. After the caterpillars hatched, the deciduous trees were badly defoliated, but no injury resulted to the pines. The small caterpillars in the pine trees, being unable to secure

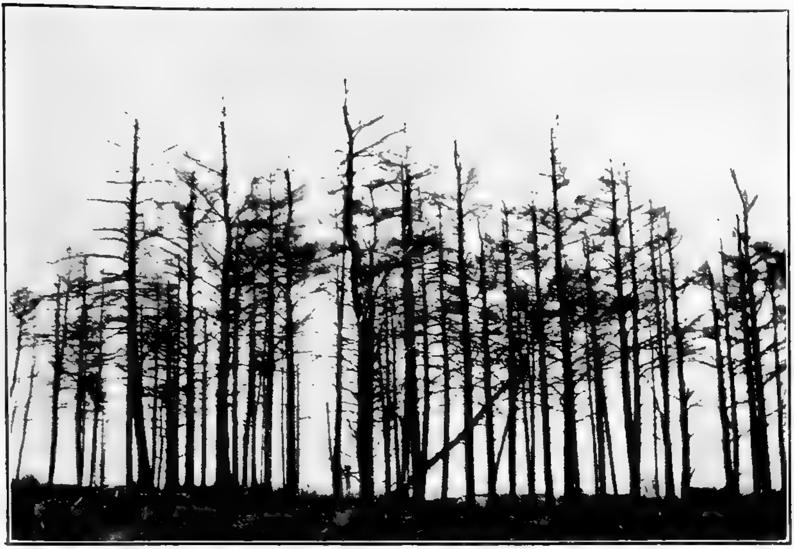


FIG. 1.—PINE GROVE KILLED BY THE GIPSY MOTH. (ORIGINAL.)

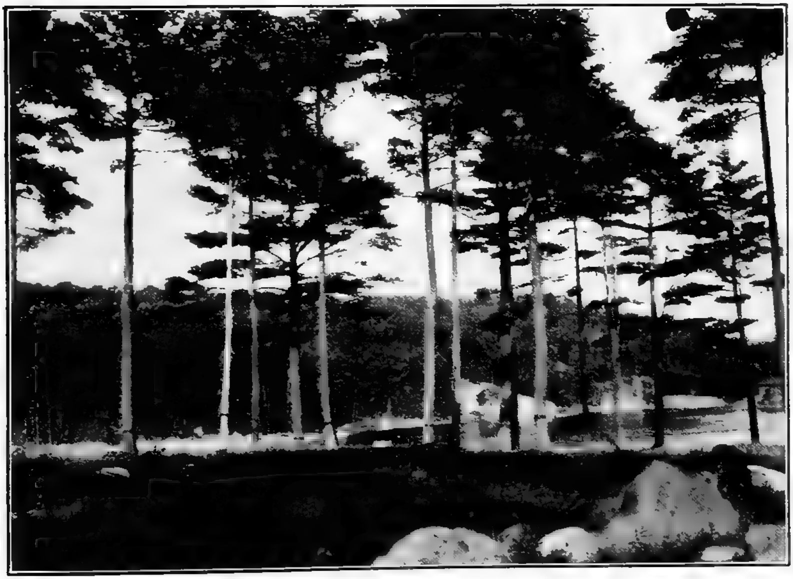


FIG. 2.—PINE TREES THAT HAVE BEEN PROTECTED FROM THE ATTACKS OF THE GIPSY MOTH. (ORIGINAL.)

proper food for their development, either died or spun down to the ground and migrated to the deciduous growth. Owing to the sticky bands on the trunks of the trees it was impossible for the caterpillars to again ascend to the foliage. This experiment was checked up by several other tests made by the state office, all of which showed the same results. (See Pl. IX, figs. 1, 2.)

The practice at present in handling coniferous woodland is to cut out all the deciduous growth which will furnish food for the young caterpillars, and if the pines are well banded with tanglefoot early in the summer, and these bands kept viscid during the caterpillar season, no further treatment is necessary. These experiments have resulted in the adoption of a simple and comparatively cheap method of preventing the destruction of valuable coniferous woodland, and as trees of this character grow satisfactorily in most sections of the infested district it is possible to preserve and develop pine forests at a moderate expense, regardless of the presence of the gipsy moth in surrounding territory.

The greater part of the experimental work has been along the line of developing more efficient spraying methods. The use of the tower on power sprayers, which will be more fully explained later in this report, has resulted in a great saving in cost of treatment. In the summer of 1909 several tests were made with large spraying machines to determine the most effective pressures and the best size of nozzle outlets. The results indicate that on the average a $\frac{1}{4}$-inch nozzle of the type described later in this report will carry the spray 20 feet farther than a $\frac{3}{16}$-inch nozzle, and that it is necessary to maintain a pressure of over 200 pounds in order to secure satisfactory results. There are many opportunities for perfecting the present spraying outfit, and much thought is being given this matter both by the Bureau and state officials as well as by manufacturers who at the present time are selling many spraying machines in the infested region. The activity in perfecting devices will undoubtedly result in better and more economical methods in the future.

METHODS NOW USED IN FIGHTING THE GIPSY MOTH.

Most of the methods used for destroying the gipsy moth have already been mentioned, and a large number of them were in successful use at the time the work was being carried on by the State of Massachusetts during the nineties. Such methods as treating egg clusters, cleaning up brush, thinning infested woodlands, and general clearing-up measures have not been improved to a great extent. The use of burlap has been continued from year to year, but owing to the expense involved in applying and tending it throughout the season it is not now considered as satisfactory a method as the more recent system of banding the trees with tanglefoot. This is especially true since the brown-tail moth became abundant in the orchards and woodlands. Many of the caterpillars of this insect seek the burlaps when they are about to spin their cocoons for the purpose of pupation, and the serious poisoning which results to the men employed when turning such burlaps makes thorough work well-nigh impossible. Every season hundreds of men suffer extremely from this trouble, and in many cases efficient and well-trained workers are obliged to resign rather than attempt to continue on the work. This is leading to a general discontinuance of the burlap method of treating the gipsy moth. The tanglefoot bands are very satisfactory and the men are enabled to work with less discomfort. The methods used in cutting out zones along infested roadways has been in strict accordance with the latest ideas of modern forestry.

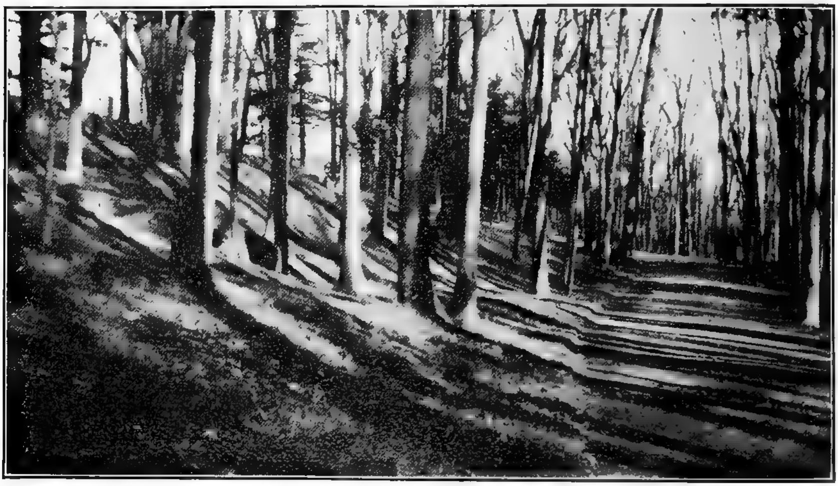


FIG. 17.—Roadside area, showing how the grass has been induced to grow by thinning out the trees and clearing away the underbrush in gipsy-moth control work. (Original.)

By adopting the best known methods in thinning and pruning, the trees which remain are in sound condition, and with the care which is given from year to year after the roadways have once been thinned they have a favorable opportunity to make a satisfactory growth. In many of these cleaned areas, which are kept free from undergrowth by mowing them in August, it has been possible to induce a stand of grass which greatly improves the entire appearance and condition of the roadside. (See fig. 17.)

Perhaps the greatest advancement has been made in spraying with arsenicals. Since the discovery of arsenate of lead this substance has practically superseded all other poisons for use against leaf-eating insects of all kinds. During the season of 1909 nearly

500 tons of this poison were used in New England for spraying the trees. Considerable spraying was done to destroy the elm leaf-beetle (*Galerucella luteola* Müll.), and this poison was used exclusively in the work. The best results are secured in spraying for the gipsy moth when the caterpillars are very small, but in covering so large an area it is impossible to provide machines enough to do all the work early in the season. Ten pounds of arsenate of lead to 100 gallons of water is a satisfactory strength to use, but after the caterpillars are half grown it is often desirable to increase this amount to 12 or 15 pounds to the same amount of water. Spraying late in the season after the larvæ are nearly fullgrown is of doubtful advantage, as the caterpillars are very resistant to poison, and as a rule will pupate and transform to moths.

The power spraying machines used in 1909 were superior in every way to any that had been designed previously, and plans for improvements on these machines have been considered for the work next season. Barrel sprayers fitted with hand pumps are used to some extent for treating shrubbery and orchards, and in some cases high trees are treated by using these outfits, especially when it is necessary to prevent buildings from becoming discolored by the poison. The use of these small outfits is impracticable when it is necessary to cover in a period of six weeks the large areas which must be sprayed, and as a result of varied tests of power outfits a system has been devised for using what is known as "solid-stream spray."

About 1895 Mr. J. A. Pettegrew, who was then superintendent of Prospect Park, Brooklyn, N. Y., constructed a steam spraying outfit for use in treating the trees which were being severely injured by the elm leaf-beetle. Sufficient pressure was developed to spray high trees from the ground, the shape of the nozzle being such that a solid stream was carried high in the air, where it was broken into a mist. This sprayer was described and illustrated by Dr. L. O. Howard in an article on spraying.[a] Soon after Mr. Pettegrew became superintendent of the Boston city parks he used a similar outfit for spraying.

In 1905, this method of treatment was tested by Gen. S. C. Lawrence, of Medford, Mass., who was carrying on extensive spraying operations to protect the trees from the gipsy moth. This outfit was built by a Boston firm, and was equipped with a high-power gasoline engine instead of with steam to generate power. The experiment was successful and since that time the use of outfits built on the same general lines has been gradually increasing. Mr. George H. Kermeen, one of the representatives of the firm alluded to, was an early advocate of this system of spraying, and in addition to making improvements in the outfits succeeded in interesting many people in their use.

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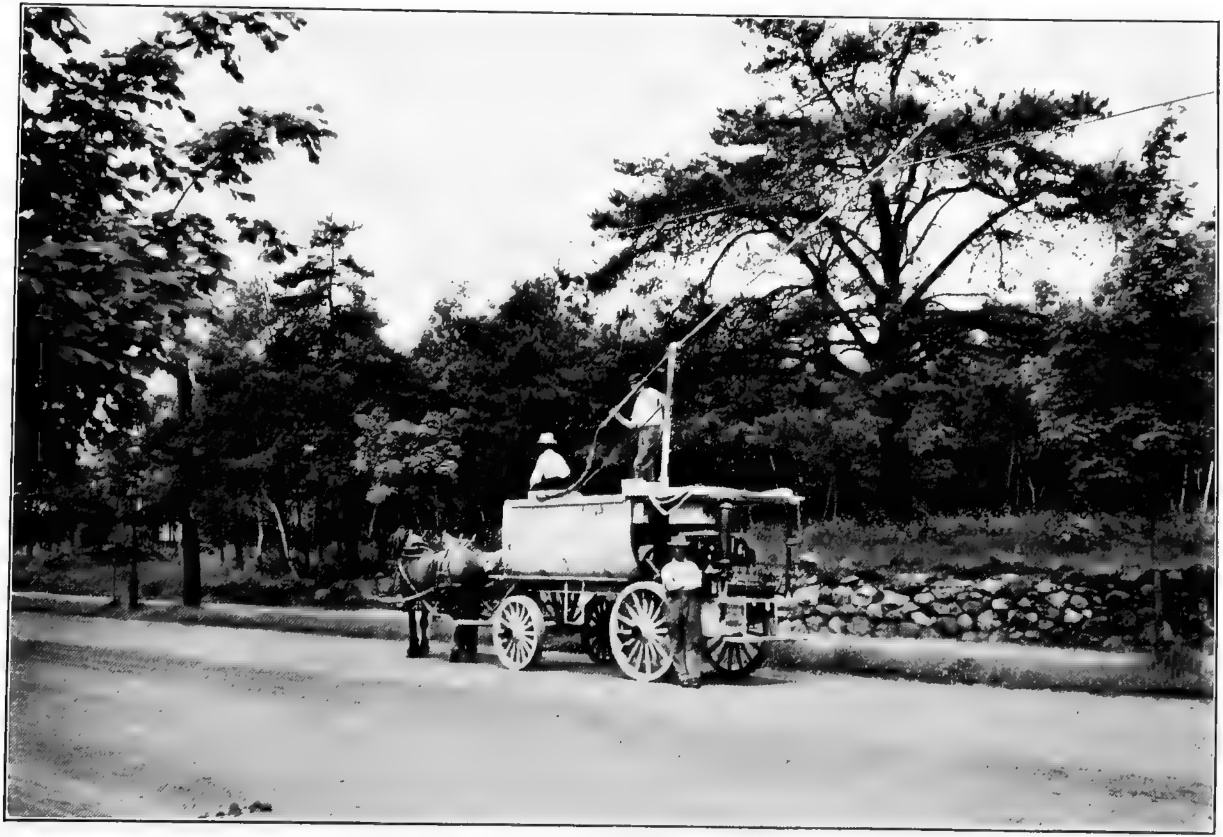
[a] "The use of steam apparatus for spraying," Yearbook, U. S. Department of Agriculture, 1896.

Experiments were carried on under the direction of Mr. A. H. Kirkland and Mr. L. H. Worthley, and others connected with the state office in Massachusetts, and considerable work along this line has been attempted by Mr. Rogers and others connected with this office, and the results have been of benefit to all workers against the moths. The most successful machine thus far designed is provided with a multiple-cylinder (usually triplex) pump which is connected by a clutch to a gasoline engine of the marine or auto type. The engine is provided with two or more cylinders. The four-cycle type of engine has given the most successful results. A bronze pump is used, as this metal accommodates itself to sudden fluctuations in pressure and is not affected as readily with arsenate of lead as those made of cast iron.

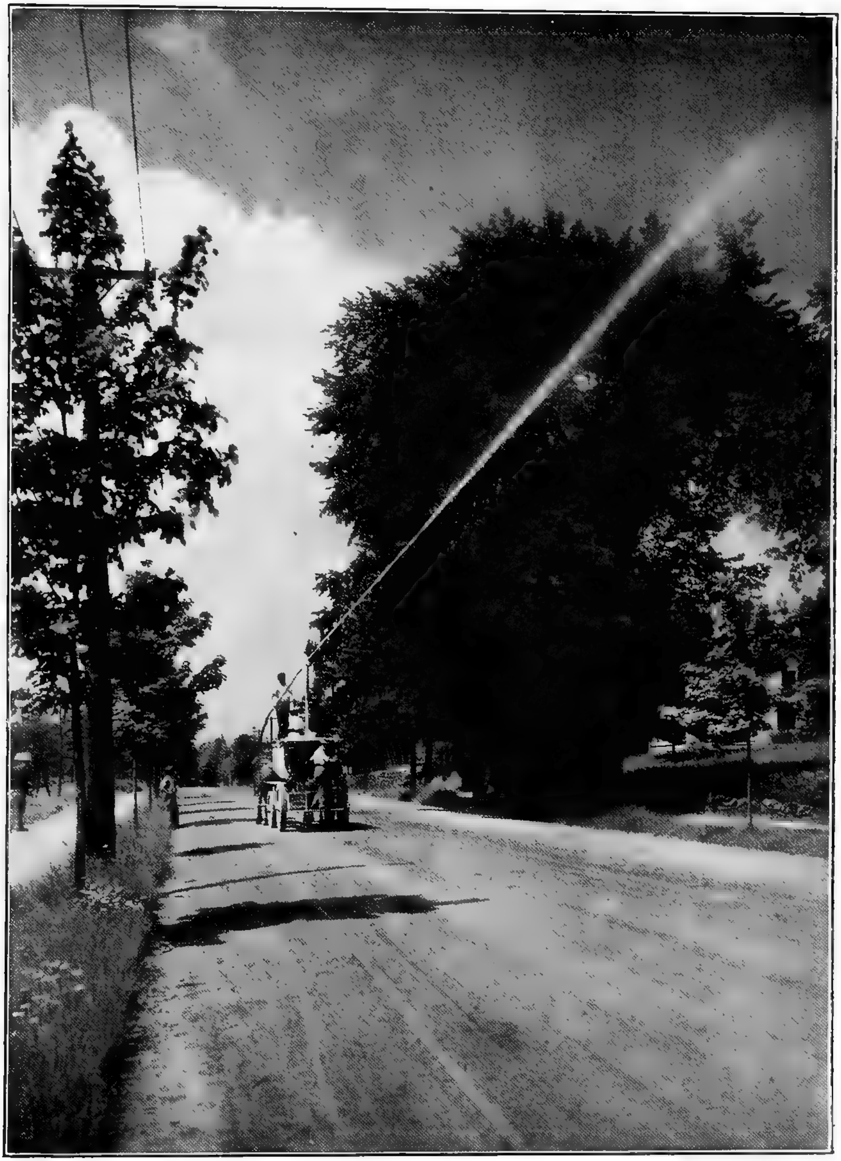
The pump must be capable of delivering 35 gallons per minute and maintain a pump pressure of at least 200 pounds. This requires a 10-horsepower engine. Piping is arranged so that water may be pumped into the tank from accessible wells, ponds, or streams, and solution pumped from the tank and not discharged by the nozzle returns either to the tank or into the pump suction. A large, strong air-chamber is necessary in order to avoid sharp shocks to the pump and also to equalize the pressure. Batteries should be placed where there is as little jarring as possible, away from the heat of the engine, and where water will not reach them. One of our machines has been fitted with a magneto with excellent results. Engines and motors of the two and four cycle types have been used and both water and air cooled engines have been tested. Until recently only gas engines of the stationary type were used, but last summer the two-cylinder marine motor, water cooled, gave excellent results, and a four-cylinder engine of this class will perhaps be still more satisfactory.

The agitation of the solution is accomplished by a shaft fitted with 2 or 3 two-bladed propellers, which passes through the lower part of the tank. It is operated by the engine so that the poison is thoroughly mixed. One-and-one-fourth-inch hose has been used for spraying with these machines, but at the present time 1-inch hose is coming into favor. The nozzle is of much the same type as that used on fire hose, being fitted for interchangeable tips, varying from ⅛-inch to ¼-inch aperture.

The machinery is mounted on the back part of a wagon truck, the front part being occupied by a 400-gallon to 500-gallon U-shaped tank. The trucks are as short as possible to accommodate the tank and necessary machinery and are provided with stout springs and brake. They are also built so that the front wheels will cut under the tank, as this is of advantage in turning around in narrow streets.



ONE OF THE TEN HIGH-POWER SPRAYING OUTFITS USED IN THE GIPSY MOTH WORK OF THE BUREAU OF ENTOMOLOGY. (ORIGINAL.)



HIGH-POWER SPRAYING OUTFIT IN USE IN TREATING ROADSIDE TREES. (ORIGINAL.)

When a machine of this type (Pl. X) is used and a pressure held at from 200 to 250 pounds, trees from 60 to 75 feet high can be thoroughly sprayed from the ground. It is necessary in spraying the woodland areas to use long lines of hose, and this requires the use of a considerable number of men to move the hose about rapidly, so that the spray material can be well distributed by the man holding the nozzle. In the work along roadsides this system was used in 1907 with satisfactory results, but the time required for moving the hose greatly increased the cost of treatment. In order to diminish the cost of applying poison to the roadside areas, and also to enable the workmen to treat a greater mileage in a given length of time, a special arrangement was devised by Mr. Rogers which is known as a "water tower." This is set up on top of the tank and is mounted on a mast 6½ feet high made of 2½-inch piping which is provided with braces to hold it in perpendicular position. It is attached to the top of the tank with bolts so that it can be laid down when not in use. At the top of the mast is a threaded street L made on free to the mast and a T is made onto the L in such a manner as to provide what is practically a universal joint. Through the T a length of 1¼-inch, 16-gauge steel tubing is placed, which is fitted with collars to hold it firmly in position. The tube is about 20 feet long; at the outer end the nozzle is attached, while to the other, which extends only about 4 feet from the point of attachment to the mast, is coupled the hose carrying the solution.

The tube near the end where the hose enters is reenforced by a quantity of lead which makes it nearly balanced on the mast. The nozzle is raised by lowering the reenforced end of the tube, and when the sprayer is in operation the nozzle is about 25 feet from the ground. With this arrangement, if the pressure is maintained at 200 pounds and a ¼-inch nozzle used, trees 80 to 90 feet in height can be readily sprayed. If the wind is light or favorable, a strip along one side of the road 100 feet deep, or more, can be treated. It is impossible to use this arrangement with satisfactory results if the wind is blowing from the strip, but under favorable conditions good work can be done if the sprayer moves along the road while the machine is in operation. (See Pl. XI.) It is more effective to spray these strips twice, as this assures better distribution of the poison. A modification of this system was tried during the past summer and consisted simply of using the tower for elevating the spray and treating the high trees and growth as far back as possible from the roadway, while at the same time another hand nozzle, with smaller tip of the same type as the one on the tower, was operated by a man standing on the top of the tank. The latter nozzle was used for treating the trees close to the road, and by this modification more thorough work was done. (See fig. 18.)

It is obvious that the tower can not be used except for treatment of roadsides, and where woodland areas are to be sprayed it is often necessary to lay long lines of hose from the sprayer, which should be located as near as possible to a supply of water. The State of Massachusetts has conducted large spraying operations over thousands of acres of forests of this character in the North Shore district with excellent results. In some cases a line of hose more than one-fourth of a mile long has been used, and it was possible to maintain sufficient pressure at the nozzle to do satisfactory work. Woodland work of this character is very expensive, owing especially to the amount of labor required to carry the hose. A machine and crew of men can usually cover about 12 acres of woodland per day, the entire cost of treatment averaging about $10 per acre. Roadsides can be treated, where the tower is used, for about $2 per acre, and it is possible under favorable conditions to spray 2 miles in a single day.

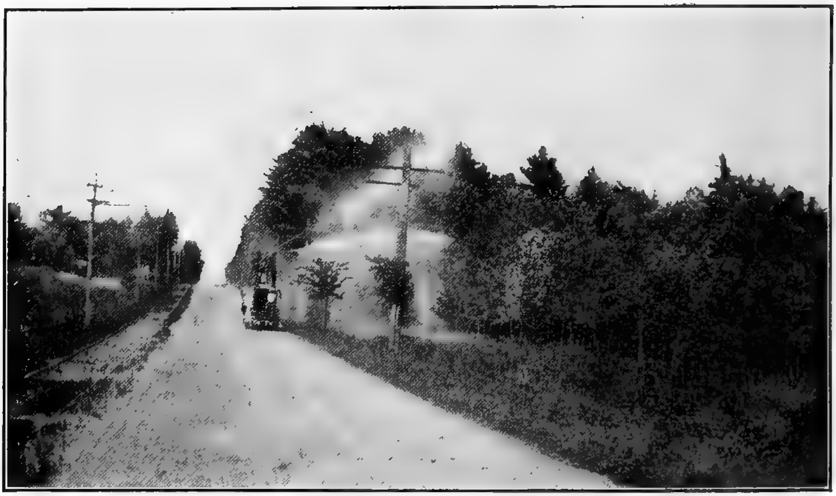


FIG. 18.—Spraying a roadside, using a combination tower and hand nozzle, so as to throw two streams. (Original.)

With the last mentioned outfit it is necessary to employ two men to operate the nozzles, an engineer to look after the machine, and a team and driver. A driver with a horse and wagon accompanies each sprayer with a supply of poison, gasoline, extra hose, etc. The driver of the supply wagon is required to post warning notices in the treated strips, which indicate that spraying has been done, so that owners of cows and other animals will not permit them to feed on the sprayed foliage or grass.

Under favorable circumstances from 4,000 to 5,000 gallons is sprayed out in 8 hours, but this amount is sometimes reduced by each machine, owing to pump or engine troubles.

COST OF METHODS EMPLOYED.

In the gipsy moth work it is very necessary to know the approximate cost of cleaning up or caring for any given infested area. The treatment work attempted by the Bureau has been principally along the line of caring for trees growing near wooded roadsides, while that of the States has covered infested areas of all kinds. In the latter work, especially in woodland areas, much money has been expended in thinning out the trees and putting the forests in the best possible condition, so that the moth can be successfully treated. Special attention has been paid to leaving trees which would be the most profitable, and also those which are to some extent immune from the feeding of the insect.

Mr. L. H. Worthley, assistant forester in charge of moth work for the State of Massachusetts, who has had wide experience in cutting-out operations, states that woodland can be properly thinned (not pruned) and put in condition for treatment measures against the gipsy moth at a cost ranging from $15 to $35 an acre. This variation depends on the character and size of the trees to be cut. The first roadside work done by this office where considerable heavy timber was cut cost about $40 an acre for thinning, burning, pruning, and creosoting egg clusters. As the force of men became more experienced in the work it has been possible to reduce the expense of cutting out these roadside strips. The average cost of work on over 30 miles of strips last fall amounted to $27.50 an acre. It may seem at first glance as though this method required an excessive expenditure of money; nevertheless it should be stated that the gipsy moth can not be successfully controlled unless the woodland is properly thinned and dead wood removed. In addition to this, if hollow trees are allowed to remain it is almost impossible to keep the insect in subjection. Another feature which should be pointed out is that although the first expense of cutting is large, the cost of caring for the area in future years is greatly reduced. Our data show that as a result of putting the roadsides in good condition for future treatment it has been possible to reduce the amount each year which must be expended for destroying the caterpillars and egg clusters.

Many experiments have been carried on for the purpose of decreasing the cost of spraying work. The adoption of the water tower on the tanks has materially assisted in this direction. A careful record of the spraying this year shows that over 360 miles of roadway were sprayed on both sides. By taking into account the entire cost, including labor, poison, supplies, fuel, and a liberal allowance for depreciation on the outfits used, it should be possible to spray roadsides for about $2 an acre.

If spraying could be relied on to control the gipsy moth, the problem would be greatly simplified, but unfortunately it is impossible to destroy all the caterpillars by spraying, and it is usually necessary to supplement the work either with burlap or tanglefoot, and to creosote all of the egg clusters that can be located during the winter. The cost of these methods is difficult to determine, as there is much variation in expense owing to the character of the infestation, the size of trees, and the locality in which the work is to be done. In general it may be said that woodland can be pruned, egg clusters creosoted, and brush cut and burned for $25 to $30 an acre; tanglefoot applied and tended for the season for $5 to $6; sprayed for $2 to $10; creosoted the following winter for $5, and should be kept free from injury by the gipsy moth for $2 an acre for each year thereafter.

VALUE OF NATURAL ENEMIES IN CONTROLLING GIPSY AND BROWN-TAIL MOTHS.

The influence exerted by native birds and insect enemies of the gipsy and brown-tail moths in this country has already been mentioned. As soon as the work was resumed by the State of Massachusetts, it was found that in some sections of the territory infested by the brown-tail moth large numbers of caterpillars were dying from a fungous disease. The matter was investigated by assistants employed by Mr. Kirkland in 1906, and specimens of the disease-bearing caterpillars were referred to Dr. Geo. E. Stone, botanist of the Massachusetts agricultural college, who stated that the cause of the death of the caterpillars was a fungus known as *Empusa aulicæ* Reichardt. This disease destroyed millions of caterpillars during the spring and early summer of 1906, and it has been found quite frequently since that time in Massachusetts, New Hampshire, and Maine. It works on both small caterpillars in the webs and the larger ones which feed during the early summer. This has assisted in checking the increase of the insect, especially in the sections of Massachusetts where it first became seriously injurious. The development of this fungus is influenced largely by weather conditions and during some years it has not greatly reduced the number of caterpillars.

During the past two or three years large numbers of caterpillars of the gipsy moth have died from a disease which is popularly known as the "wilt" or caterpillar cholera. This has been prevalent particularly in badly infested areas, especially in woodland, where many of the trees have been nearly defoliated. It seems to develop more rapidly on caterpillars which have not had sufficient nourishment, although in some places it was present where a considerable amount of foliage remained. The caterpillars attacked by this trouble become sluggish and soon die, the inside of the body becoming semiliquid and putrid. When the cholera is prevalent, the trunks of trees below tanglefoot or burlap bands, where the caterpillars congregate, are sometimes completely covered with dead or dying larvæ. Isolated cases of caterpillars that had died from this disease were observed previous to the year 1900, but at that time the insects killed by it were relatively few. This trouble, which is supposed to be a disease known as "flacherie," was recognized as fatal to the silkworm many years ago.

Both of the diseases above mentioned are being carefully investigated by specialists of Harvard University in cooperation with the office of the Massachusetts state forester.

THE INTRODUCTION OF PARASITES AND NATURAL ENEMIES OF THE GIPSY AND BROWN-TAIL MOTHS.

Although the work of introducing parasites and natural enemies of the gipsy and brown-tail moths is entirely separate from the field work which is being carried on for the control of the insects mentioned, a brief statement is made concerning it, as it has an enormous practical bearing on the problem at hand.

It is evident that if the natural enemies of these insects can be introduced into the infested district in large numbers and be able to survive our climatic conditions and reproduce in the same ratio that they do in their native homes, it should be possible by this means to largely curtail the destruction that is now prevalent in New England. An effort in this direction has been carried on for the past four years by the Bureau of Entomology in cooperation with the State of Massachusetts, and Dr. L. O. Howard, Chief of the Bureau, has had the matter in charge.

A considerable number of parasites and natural enemies have been received and liberated, and conditions at the present time seem to warrant the hope that eventually much good will result from this work. It should be borne in mind, however, by some of those who are overenthusiastic as to the possibilities of controlling the insect pests by means of their parasites or natural enemies, that few cases are on record where work of this sort has been entirely effectual. Furthermore, it should be pointed out that the gipsy moth was liberated in this country nearly twenty years before it became such a serious pest as to cause widespread notice and the adoption of active measures for its suppression. This being the case, it will undoubtedly be several years before it will be possible to notice definite results from the reproduction of parasites in the field, and until it has been demonstrated that natural enemies can control the situation it is folly to curtail the amount of hand work which is being employed for the destruction of these pests.

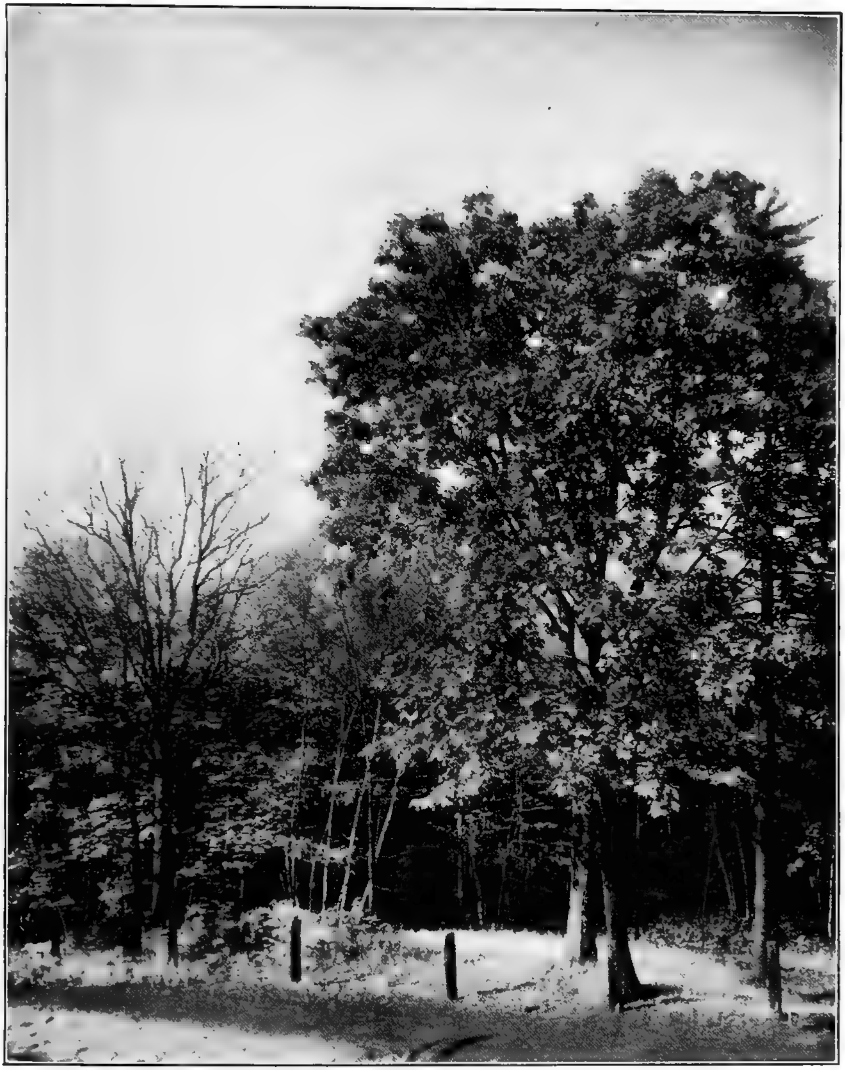
VALUE OF THE WORK OF SUPPRESSION TO THE FARMER AND FRUIT GROWER.

From what has been already mentioned in this report it must be apparent that the strenuous effort being made to control the spread of the gipsy and brown-tail moths is of great value to farmers and fruit growers, especially to those who live outside the infested district. Should these insects spread over the United States and cover the same range which they now occupy in foreign countries the cost of controlling them and the damage which would result to orchards and to forest and shade trees would be enormous. The more progressive citizens throughout the country who understand the situation must appreciate the danger of the spread of these pests and are undoubtedly in sympathy with the work which is being carried on to restrict their increase. The residents of the infested district who have seen the devastation caused understand the necessity for thorough and persistent work if the trees are to be preserved. (See Pl. XII.) This is especially true in cities and towns where most of the shade trees have a desperate struggle to maintain an existence and where, owing to unfavorable conditions for tree growth, it is difficult to replace trees which have died from any cause. The hand methods of suppression which are being used are the best that have been devised and new or more effective methods are eagerly sought for by all who have a hand in managing the work.

The introduction of parasites and natural enemies, and the study and attempt to make use of the diseases of the insect which are known to exist, are being pushed as rapidly as possible. Both branches of the work are being conducted for the ultimate benefit of the property owners in the infested district and for the protection of all those who are fortunate enough to reside beyond its limits. The cost of protecting trees from such well-known insects as the San Jose scale, the codling moth, the elm leaf-beetle, and many other insects which prey upon them in more or less restricted localities throughout the United States, represents an enormous annual expenditure of money. This cost is ultimately met by the consumer of the products, and in the moth-infested district (fig. 19) by the tenant who lives on the property where treatment is applied.

SUGGESTIONS TO THE OWNERS OF PRIVATE PROPERTY IN THE INFESTED DISTRICTS.

It is evident that little progress can be made in controlling such insects as the gipsy and brown-tail moths without the hearty cooperation and intelligent interest of owners of private property in the infested districts. As a rule, owners have shown great appreciation of the work which is being carried on and many have expended large sums of money in caring for the trees on their own property. In sec-



VIEW SHOWING CONTRAST BETWEEN TREES PROTECTED FROM THE GIPSY AND BROWN-TAIL MOTHS AND THOSE UNPROTECTED. (ORIGINAL.)

[The tree at the left is an oak defoliated by brown-tail caterpillars and containing many of their webs at tips of branches.]

tions which are now only slightly infested less interest is taken in the matter because of the fact that few of the citizens thoroughly understand the damage which these pests are capable of inflicting.

Owners of orchards are advised that if modern methods of horticultural practice are adopted it is possible to put their trees on a paying commercial basis in spite of the presence of these insects.

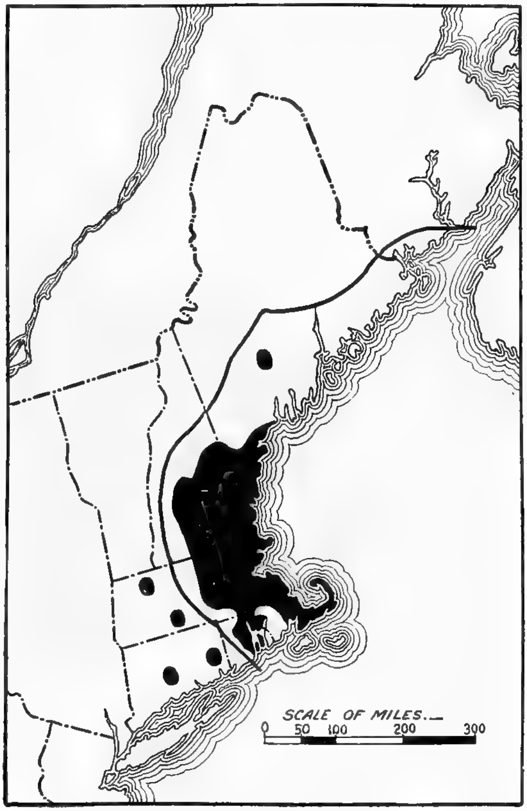


Fig. 19.—Map of New England, showing present area infested with the gipsy moth and the brown-tail moth. The black area is that infested with the gipsy moth; the brown-tail moth occupies all of the area to the right of the black line. (Original.)

Too many New England orchards yield no great revenue at the present time because of neglect, which is either due to lack of interest in caring for the trees or to ignorance of the possibility of making them sources of revenue. (See fig. 20.) Few intelligent farmers expect to harvest a profitable crop of potatoes without giving the land proper culture and treating the vines to protect them from the ravages of the potato beetle, and if the owner of fruit trees expects an income from this source he must give his orchards the best of care and protect the trees and fruit from the many insect enemies which prey upon them. The orchards of New England should be thoroughly pruned and trees which do not yield good varieties of fruit or which are in poor condition should be cut down and burned. Those remaining should be sprayed to destroy the insect pests which already attack them, and if the gipsy and brown-tail moths are present the additional expense of fighting them will not prevent the growing of a profitable crop.

Owners of woodland on which the trees are of marketable size should cut the timber if the gipsy moth is prevalent in the region. Care should be taken in doing this work to cut out all poor and worthless trees, and if possible to leave for reforesting purposes vigorous specimens of ash, maple, pine, or coniferous trees of which the insect is not especially fond and which can be protected with the least possible expense. (See fig. 21.)

The planting or preservation of ash and hickory is recommended as the wood is of high value and these trees are not subject to attack by the brown-tail moth. Planting pine or other coniferous trees for reforesting purposes is also advisable, as the region is suited to their growth and these can be protected from moth injury at slight expense.

It is probable that many of the forests containing oak or other trees which are preferred by these insects must in time give way to species less subject to attack. In the meantime the owner should take advantage of the opportunity to harvest his merchantable trees that are susceptible to attack and foster the growth of other species that will not be destroyed.

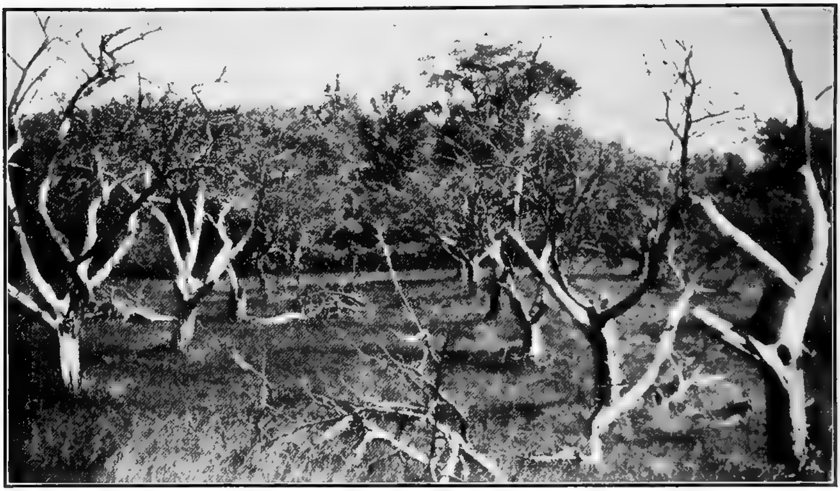
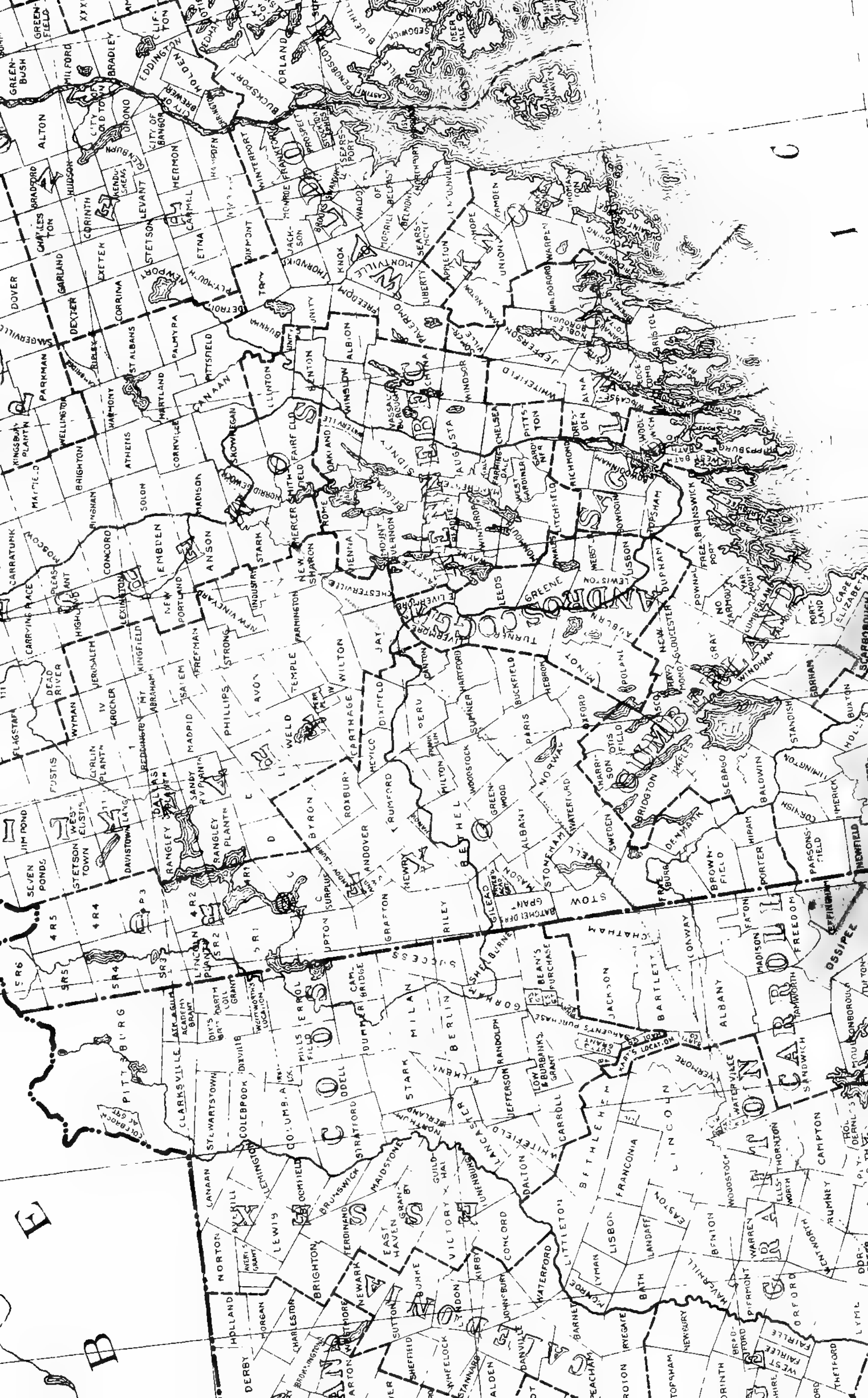


FIG. 20.—Neglected apple orchard in which the trees have been killed by the gipsy moth. (Original.)

In cities and towns much progress can be made by cutting out neglected areas of worthless trees and in some sections the number of trees on the streets or on private property can be reduced and still provide as much shade as is desirable. If this work is intelligently done no injury will result to the property; in fact, a direct benefit will accrue and the cost of future work required to hold the moths within reasonable bounds will be greatly decreased.

THE OUTLOOK.

At the time the work on the gipsy moth was abandoned by the State of Massachusetts in 1900, over $1,000,000 had been spent in an attempt to exterminate the pest. Since the work was resumed in 1905 nearly $4,000,000 has been expended by the different States in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BROOKSVILLE
SEDGWICK
BLUEHILL
BROOKLIN
DEER ISLE
VINALHAVEN
ISLESBORO
ALTON
OLD TOWN
ORONO
CITY OF BANGOR
GLENBURN
HAMPDEN
HERMON
WINTERPORT
FRANKFORT
PROSPECT
STOCKTON SPRINGS
SEARSPORT
BRADFORD
HUDSON
KENDUSKEAG
LEVANT
CARMEL
CHARLESTON
CORINTH
STETSON
ETNA
DIXMONT
MONROE
JACKSON
BROOKS
SWANVILLE
WALDO
BELFAST
NORTHPORT
LINCOLNVILLE
CAMDEN
ROCKPORT
THOMASTON
ROCKLAND
ST. GEORGE
CUSHING
FRIENDSHIP
HOPE
UNION
WARREN
APPLETON
SEARSMONT
MORRILL
BELMONT
KNOX
MONTVILLE
LIBERTY
THORNDIKE
TROY
PLYMOUTH
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BURNHAM
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FREEDOM
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FRYEBURG
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PORTER
PARSONSFIELD
NEWFIELD
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BEAN'S PURCHASE
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ALBANY
TAMWORTH
PITTSBURG
CLARKSVILLE
DIXVILLE
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DUMMER
MILAN
BERLIN
GORHAM
RANDOLPH
SARGENT'S PURCHASE
CRAWFORD'S GRANT
HART'S LOCATION
LIVERMORE
WATERVILLE
SANDWICH
MOULTONBOROUGH
STEWARTSTOWN
COLEBROOK
COLUMBIA
ODELL
STARK
KILKENNY
JEFFERSON
LOW & BURBANKS GRANT
CARROLL
BETHLEHEM
LINCOLN
THORNTON
CAMPTON
HOLDERNESS
COLEBROOK ACADEMY GRANT
STRATFORD
NORTHUMBERLAND
LANCASTER
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FRANCONIA
WOODSTOCK
CANAAN
AVERILL
LEMINGTON
BLOOMFIELD
BRUNSWICK
MAIDSTONE
GUILDHALL
GRANBY
VICTORY
LUNENBURG
LITTLETON
LISBON
EASTON
BENTON
ELLSWORTH
WARREN
RUMNEY
WENTWORTH
NORTON
AVERILL'S GRANT
LEWIS
FERDINAND
EAST HAVEN
BRIGHTON
NEWARK
BURKE
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CONCORD
WATERFORD
LYMAN
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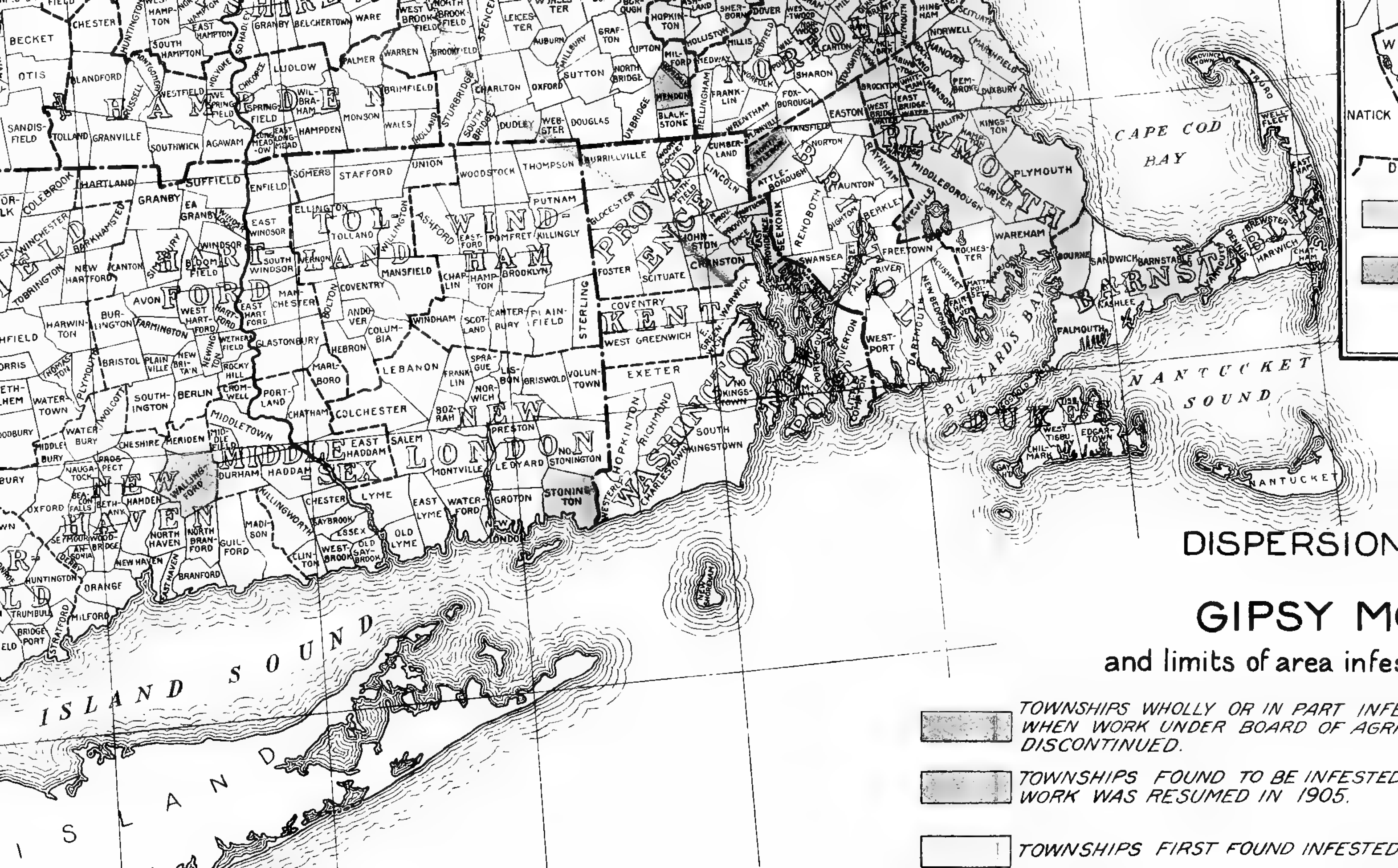

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WHEN WORK UNDER BOARD OF AGR
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TOWNSHIPS FOUND TO BE INFESTE
WORK WAS RESUMED IN 1905.
TOWNSHIPS FIRST FOUND INFESTED

New England, which are infested with the gipsy or brown-tail moths, by private property owners, and by the United States Government, in an attempt to suppress them and to prevent their further dissemination. Every known means which promised good results in accomplishing this end has been tried in the field. The best methods of hand suppression have been carried on extensively and foreign countries have been literally ransacked for parasitic and predaceous enemies of the moths in the hope that they may in due time develop into a most important factor in checking the ravages of these insects. Owing to the ability of both sexes of the brown-tail moth to fly considerable distances, it has been impossible to prevent its rapid spread to new localities (see fig. 22), but the methods employed in the worst infested sections have afforded a large amount of relief from the injury which this insect causes.

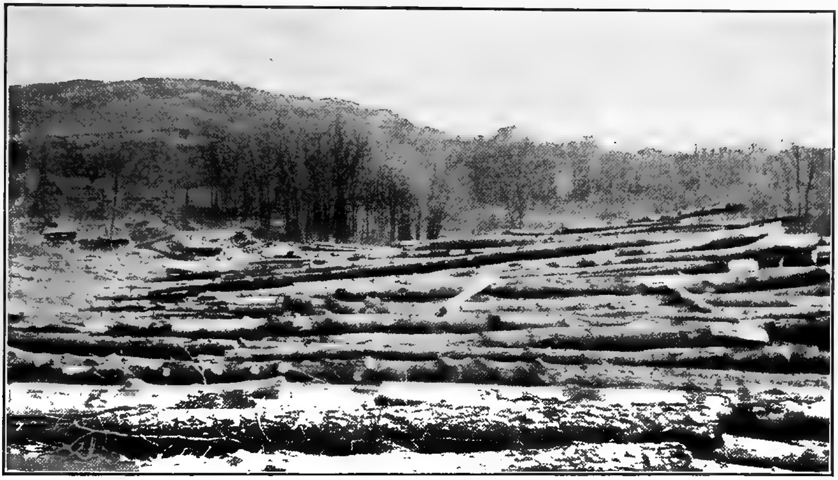

FIG. 21.—View of a hill where all the timber was cut to prevent its destruction by the gipsy moth; pile of logs in the foreground. (Original.)

Each year more or less territory has been found infested by the gipsy moth where the pest was not previously known to exist, so that the territory now known to be infested covers in the aggregate about 7,900 square miles. (See Pl. XIII.) At a conservative estimate three-fourths of this area consists of wooded land, while the balance is made up of residential sections, orchards, and farm lands. While the States in the infested section and the United States Government have done much work in the residential sections and along some of the principal roadways, it has been impossible to inspect the large forest area so as to determine the present state of infestation. So long as some of these areas remain badly infested it is difficult to prevent further dissemination of the gipsy moth. The methods adopted of keeping roadways clear has undoubtedly been a factor in preventing many colonies from becoming established at distant points, but although nearly 250 miles of roadways have been treated in this manner in Massachusetts, there is still a very large mileage of trunk roads which can not be given proper attention with the funds at hand. The need of more work in the infested area is very urgent, as this is the only possible way to prevent the continued spread of the insect until the parasites and natural enemies which are being introduced have an opportunity to show their capacity for reducing the pest. The importance of the work against this insect extends beyond state lines or sectional lines and should receive the cordial support of all who are interested in agriculture, horticulture, or forestry.

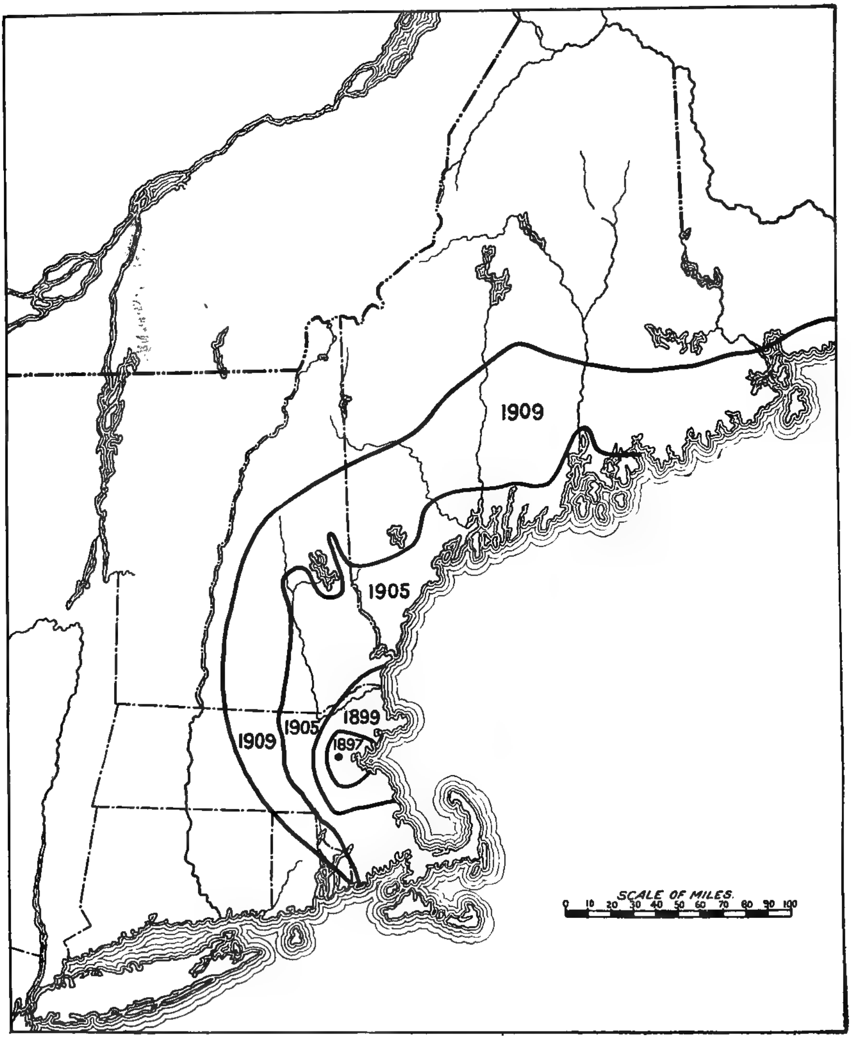

FIG. 22.—Map of New England, showing areas infested by the brown-tail moth from 1897 to 1909. (Original.)

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U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 453.

DANGER OF GENERAL SPREAD OF THE GIPSY AND BROWN-TAIL MOTHS THROUGH IMPORTED NURSERY STOCK.

BY

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WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., March 27, 1911.

SIR: I have the honor to transmit, for publication, a paper dealing with the danger of the general establishment throughout the United States of the gipsy moth and the brown-tail moth, which have been during the preceding two years, and are again the present year, imported from European countries on nursery stock and widely distributed in the United States. While every effort has been made to examine and disinfect such imported stock, it is by no means certain that all of the infested shipments have been reported and examined by inspectors, especially as, in the absence of any law, all reports and work of this kind are more or less voluntary. There is, therefore, considerable danger that the brown-tail moth, or perhaps the gipsy moth, has already become established in one or more interior points.

This paper gives a record of the infested importations during the last two years and descriptions of nursery conditions in Europe, showing the nature of the infestation there, and concludes with a brief description, with illustrations, of the two moth pests which are now being thus imported. The publication is, therefore, a warning to users of such imported stock and gives descriptions and figures enabling the prompt recognition of either of these pests wherever they may become established.

The nonexistence of a general law providing for the reporting of all imported stock and for uniform and thorough inspection and disinfection of such stock makes it highly desirable that the information here given should be made promptly available and widely distributed.

I recommend its publication as a Farmer's Bulletin.

Respectfully,

L. O. HOWARD,
Entomologist and Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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DANGER OF GENERAL SPREAD OF THE GIPSY AND BROWN-TAIL MOTHS THROUGH IMPORTED NURSERY STOCK.

INTRODUCTION.

Winter nests of the brown-tail moth, each filled with hundreds of young larvæ, and occasional egg masses of the gipsy moth have been brought into the United States, the former in enormous numbers, during 1909–10 on imported nursery stock, and the importations for the season of 1911 are again bringing in these brown-tail moth nests. This infested stock, coming largely from nurseries in northern France, has been scattered widely over the United States east of the Rocky Mountains, and while every effort has been made to trace these importations and inspect and disinfect them the probability of many unreported shipments or inefficient inspection is very great.

A general warning is therefore given to all users of such imported plant stock, namely, to nurserymen, fruit raisers, and purchasers of ornamentals for city or park planting, to keep all such imported stock under strict watch to see that these pests do not develop.

As an aid in this direction this bulletin has been prepared. It gives a record of the infested importations of the past two years, a review of the nursery conditions in Europe showing the nature of contamination there, and a brief description, with illustrations, of the two moth pests which are now being imported and widely distributed.

IMPORTATIONS OF INFESTED NURSERY STOCK OF 1909–1911.

Space will not be taken to give the details of the shipment and distribution of infested nursery stock during these years. Some idea of the situation can be gained, however, from the following brief summary of importations, drawn largely from the annual reports of the Bureau of Entomology by Dr. Howard for the two years in question.

BROWN-TAIL MOTH NESTS IMPORTED IN 1909.

Early in 1909 it was discovered that nests of the brown-tail moth, filled with hundreds of small hibernating larvæ, were being introduced into this country on imported European nursery stock—chiefly from northern France—and distributed into many States. These brown-tail moth nests were first reported in connection with a consignment of seedlings shipped from Angers, France, to New York. The nests were discovered by the New York State inspector, and the information was communicated to the Bureau of Entomology by the commissioner of agriculture of that State.

A little later information came from Ohio that the winter nests of the brown-tail moth had been found on seedlings imported into that State from the same locality in France.

Warning letters were promptly sent out by Dr. L. O. Howard, chief of the Bureau of Entomology, to the different entomologists, and special arrangements were made with the customs office, through the kindness of the Secretary of the Treasury, and by agreement with the railroads, so that this bureau was to be informed of all cases of plants received at customs or subsequently handled by the principal railroad companies. By this means the receipt and ultimate destination was ascertained of much of the imported stock of that year. This information was transmitted to the State inspectors and other competent persons near the points of ultimate destination of such packages and an effort was made to have all such imported material inspected.

Information was secured concerning nearly 800 shipments, divided among 35 different States. In shipments to 15 of these States, namely, Alabama, Georgia, Illinois, Iowa, Kansas, Kentucky, Maryland, Massachusetts, Missouri, Nebraska, New Jersey, New York, North Carolina, Ohio, and Pennsylvania, nests of the brown-tail moth were found, ranging in number from one nest to many nests in each shipment. These brown-tail nests—little webbed packets of leaves containing the very small hibernating larvæ to the number of 300 or 400 in each nest—were found on the seedling and other nursery stock in enormous numbers, some 7,000 nests (approximately 2,800,000 larvæ) being found in shipments to New York State alone.

In one locality in Ohio an egg mass of the gipsy moth was found and Prof. P. J. Parrott, of the New York Experiment Station, at Geneva, N. Y., found another important European fruit pest (*Hyponomeuta padella*), which had probably been introduced on these same French seedlings.

BROWN-TAIL MOTH NESTS IMPORTED IN 1910.

In view of the dangerous conditions of the shipments of 1909, a strong effort was made on the part of Dr. Howard to have the French authorities provide for the competent inspection and disinfection of material preliminary to the shipping season of 1910. In spite of promises of the authorities that such inspection would be made, the shipments of nursery stock from France in 1910 again brought to this country enormous quantities of nests of the brown-tail moth, filled with the one-fourth grown larvæ. Moreover, one shipment of nursery stock from Belgium to Louisiana contained an egg mass of the gipsy moth.

All of this imported European stock was again followed up as far as possible in accordance with the arrangement of the previous year with the customs officers and by agreement with the railroads, and all reported shipments were inspected at their destination.

Of the shipments of 1910 not less than 291 different lots were found to be infested with nests of the brown-tail moth. These went to the following States: Colorado, Connecticut, Georgia, Illinois, Indiana, Kansas, Louisiana, Michigan, Montana, New Jersey, New York, Ohio, and Virginia.

BROWN-TAIL MOTH NESTS IMPORTED IN 1911.

As a result of a thorough investigation of European conditions, which will be described later, a much better effort during the last year has been made, notably in France and Belgium, to improve the conditions of export stock, and as a result the importations of the present season of 1911 so far have shown a very notable improvement in amount of infestation. Nevertheless, the imported stock still shows occasional infestation, and such infested stock is being widely distributed. The danger as the infestation becomes less general is perhaps just as great or even greater from the very natural lessening of care or greater haste which will be given to examinations, and one overlooked nest or egg mass is quite sufficient to establish these pests.

RECORDS OF DISTRIBUTION OF THE IMPORTED NURSERY STOCK INCOMPLETE.

Nursery stock imported by dealers and sent direct in bond to destination is probably all reported and subsequently examined. Much of the imported nursery stock is, however, handled by customs brokers or receiving agents in New York, and the different packing cases are so marked that these distributing agents know where to send them, and they are distributed widely over the country, often in bond, without being examined in New York, and often without any record being made of such shipment or final destination. As pointed out by Dr. Howard in his testimony before the House Committee on Agriculture, much of such nursery stock which enters at the port of New York and is thence distributed in original packages the Government has been able to trace through the courtesy of the railroads, in addition to the regular arrangement with the customs office to advise the Department of Agriculture on the receipt of such stock. Nevertheless, the information gained from the customs office is evidently incomplete, as very often the railroad companies report the handling of stock of which no advice has been gained by the customs office, and, on the other hand, material is reported by the customs office which is not reported by the railroad companies. For this reason there is no certainty that all of the imported stock is reported, and undoubtedly some of it is miscellaneously distributed and never is examined at all. This condition of affairs, from local experience in his State, was strongly brought out by Dr. J. B. Smith, entomologist of New Jersey, in his testimony before the House Committee on Agriculture.

Dr. Smith also called attention to two other features of the importation of nursery stock which have an important bearing on the entrance of such pests as the gipsy moth and the brown-tail moth. The first of these relates to the importation by large department stores of New York, Philadelphia, and Washington, and in large interior towns, of inferior stock of ornamental plants, roses, and even fruit trees, massed down under enormous pressure in large boxes, thousands of plants in a single case. This largely worthless and often infested stock is distributed by these agencies at a very low price, or is given to the customers, and goes in small parcels here and there where it can not be followed, and necessarily entails the greatest risk of the introduction of dangerous pests and plant diseases. It is almost impossible to make any proper examination of such material even when its importation and destination are reported. Some of these shipments contain hundreds of thousands of plants, so that the chances of overlooking infestation are exceedingly great.

The other condition referred to by Dr. Smith is the importation by private persons, owners of large estates, or head gardeners, of greater or less quantities of ornamental and floral stock, such miscellaneous importations being very difficult to get advice of, and undoubtedly many of them are never reported or inspected.

CONDITIONS IN THE DISTRICT OF COLUMBIA.

A recent and very undesirable development in the introduction of foreign nursery stock has come to light in Washington, D. C., and probably is occurring in other large cities. In the latter part of March it was learned that a large shipment of miscellaneous ornamental stock had been made by a Dutch nursery firm to a local auctioneer, to be sold under the hammer, and, on the authority of the auctioneer in question, without previous arrangement. This new development seems to have arisen from an experience of the previous year (1910), where a shipment of stock was refused by the consignee and was turned over to this same auctioneer for sale. The results were evidently sufficiently satisfactory to lead the Holland firm to make the shipment of stock this year direct to the auctioneer, on the chance of a profitable sale.

The situation in the District of Columbia is probably the worst in the United States, inasmuch as there is no law whatever which authorizes the examination or inspection of nursery stock imported into the District. Examination of stock imported by local department stores, by nurserymen, and that sent for auction, as noted above, can be made only by officials of the Department of Agriculture through the courtesy of these different receivers of such stock. Very often such courtesy is scant, or refusal is made to open up the stock or separate it so that it can be properly examined. Such stock, when reported, has, however, been as thoroughly inspected as conditions permitted. It is sold to a multitude of purchasers, many of whom reside in near-by points in Virginia and Maryland, and thus finds entry into these States without the knowledge of the State officials.

NATURE OF INSPECTION AND LIKELIHOOD OF LOCAL INFESTATION.

As already indicated, the principal function of the Bureau of Entomology has been to get as complete information of importations as possible and transmit this information to the State inspectors, where such existed, of the several States. In some instances, where no local means of inspection was available, the imported material was inspected directly by agents of this bureau. In most of the States receiving infested goods the inspection made was conscientious and thorough. In some instances, however, the inspection was undoubtedly indifferent or worthless. This is illustrated by the fact that material received by a large Missouri nurseryman, and on his own statement "carefully inspected," was reshipped by him to Maryland, still infested with the brown-tail moth.

The condition of the imported nursery stock is such as to make inspection difficult and also to render it practically impossible to be absolutely sure that the inspection has resulted in the detection and destruction of all larvæ. The nests themselves are sufficiently prominent to be easily seen if the masses of thousands of plants in a case are properly separated so that each can be given individual examination. This means, however, a lot of time and absolute conscientiousness on the part of the inspector.

Many of the nests, however, in the process of packing and unpacking become broken and the minute larvæ are scattered more or less through the seedling stock and also in the packing material. Under these conditions, the chance of larvæ being overlooked by the inspector is very great. It by no means follows, therefore, that even where material is located and inspected the brown-tail moth and perhaps other pests have not been introduced. Furthermore, the unpacking is done, in many nurseries, in the open, in close proximity to growing nursery or ornamental stock, and the packing straw and wrappings are piled about and touching growing or heeled-in trees, so that plenty of opportunity may exist for the moth larvæ, in such packing material or otherwise scattered, to find lodgment and opportunity for development.

There is also, in addition to the difficulties experienced in actual inspection, the very large risk, already indicated, that many shipments are not inspected at all.

The fact that the brown-tail moth or any other pest does not develop immediately in the regions where these infested shipments are opened is no indication that such pests have not been introduced and that they will not eventually become established. When in very scanty numbers, they are inconspicuous enough to be easily overlooked for a number of years, as was illustrated in the case of the gipsy moth near Boston, which remained slowly increasing for over 20 years before it came to public notice. The brown-tail moth, brought in on roses, probably from Holland, about 1890, also had become thoroughly established over quite a large area before it was recognized, in 1897, as a new pest. The latter case is all the more instructive because the brown-tail moth was developing in the very region which was then being thoroughly examined every year for the gipsy moth. It may well be possible, therefore, that either the brown-tail moth or the gipsy moth is now slowly gaining headway at different points in one or more States as a result of the shipments of infested material of 1909 and 1910.

SIGNIFICANCE OF IMPORTATIONS OF 1909–1911.

It is scarcely necessary to comment on the tremendous danger which the importations of nursery stock of the last three seasons have brought to this country. The enormous cost of the gipsy moth and the brown-tail moth in New England is now well known. Throughout the infested districts of New England orchards have been completely destroyed and forests largely obliterated, and even where woodlands and parks have been protected at an enormous expense their beauty and value have been vastly lessened.

Massachusetts has spent millions of dollars in an effort to control these pests, and with their spread to other States the work of control has been taken up in these also. The National Government has been asked to come to the rescue, and is now appropriating $300,000 a year in the mere attempt to check the distribution of these pests along the principal highways. Massachusetts and the other infested New England States are now spending more than a million dollars a year in control work. In spite of these efforts and this enormous expenditure the gipsy moth and the brown-tail moth are steadily spreading in New England and great damage is experienced from them yearly. Extermination is entirely out of the question, and all these expenditures must go on indefinitely at a probably increasing rate, unless some natural check by means of parasites can be brought about.

In addition to the great destructiveness of these pests to orchards and forests, their establishment in any suburban residential district means an enormous depreciation in property values, as is now illustrated about the city of Boston, and very notably lessens the attractiveness of coast or mountain summer resorts. The north shore towns of Massachusetts and lower Maine resorts have already felt this influence, and for such regions as the Catskills or Adirondacks the establishment of these pests would be most disastrous, inasmuch as control over such extended forested mountains is practically impossible.

When it is realized that these two pests have been widely distributed, on imported nursery stock, in 22 States during the years of 1909 and 1910, and are now coming in on imported stock from France and Belgium, the danger to the whole country is fully apparent, and this danger applies to every orchard and to every owner of private grounds and also to our entire forest domain. The tax from these pests, should they gain foothold throughout the country, as measured by the existing cost in New England, is almost beyond estimate.

EFFECT OF THE BROWN-TAIL MOTH ON HEALTH.

In addition to the great monetary loss, the brown-tail moth exercises a very deleterious effect on health. The hairs which cover the caterpillars of this moth are strongly nettling, and not only are they so from accidental contact with a caterpillar which may fall on clothes, face, neck, or hands from an infested tree, but also from the myriads of hairs which are shed by these caterpillars when they transform to the chrysalis state. The latter fall and find lodgment on clothing, or collect on the face, neck, or hands, and frequently cause very disagreeable and extensive nettling, the effects of which may last for months. Breathed into the lungs they may cause inflammation and become productive of tuberculosis. The brown-tail rash is well known throughout the regions infested in New England and thousands have suffered from it. All of the assistants who have been connected with the Government work with these pests in the New England States have been seriously poisoned. Two of them have had to give up their work and go to the Southwest to attempt to recover from pulmonary troubles superinduced by the irritating hairs of the brown-tail moth, and the death of one man employed on the work was due to severe internal poisoning contracted in field work against larvæ.

This insect is, therefore, a most undesirable neighbor, even if it were not responsible for great injury to orchards and ornamental trees.

CHARACTER AND VALUE OF IMPORTED NURSERY STOCK.

The actual value of the importations of nursery stock which is thus jeopardizing the entire fruit and forest interests of this country, as declared at customs during the years 1907 and 1908, of which we have tabulated records, is about $350,000 annually, but little more than the sum which the United States Government is spending every year in an endeavor to eliminate the spread of the gipsy moth and the brown-tail moth, and one-third the sum which the New England States are spending annually in an attempt to control these pests.

The major part of the imported stock consists of seedling apple, pear, plum, and cherry from north France. There is also considerable importation of ornamental and flowering plants, shrubs, and trees. The latter is purely commercial, and comes in very largely for the reason that it can be produced more cheaply abroad than in this country. Of the seedling stock, it is claimed by nurserymen that the imported plum, cherry, and quince stock particularly is much better material for grafting purposes than home-grown seedlings. In the case of the apple seedlings, however, the great mass of such stock is still produced in this country and can undoubtedly be just as well produced here, if not better, than in France or elsewhere in Europe.

The stock of the last two years which has been most infested has come from northern France, accumulated from various smaller or larger nurseries, including a French seedling agency, managed by an American corporation composed largely of New York nurserymen.

If, as is claimed, some of this seedling stock is better than any that can be produced in this country, it becomes all the more imperative that such stock, or all imported stock, should be subject to rigid inspection, and that every possible means should be taken to safeguard this country from the further establishment of these two very dangerous insect pests.

EUROPEAN NURSERY CONDITIONS.

During the summer of 1909, and also again in 1910, Dr. Howard, who was in Europe principally to supervise the introduction of parasites for the gipsy and brown-tail moths into Massachusetts, made a careful inspection of the nursery regions of Holland, Belgium, and northern France, and also England.

The writer was in Europe, on a personal trip, in the summer of 1909, and made an examination of similar conditions in Holland, Belgium, and parts of Germany.

Holland probably presents the cleanest bill of health in the matter of insect pests, and particularly of the gipsy moth and brown-tail moth. This country enjoys a good inspection service, and all Dutch nurseries are carefully inspected twice each year, so there is probably less danger now from shipments from Holland than from any other country.

Belgium, in 1909, was in very bad condition, and the writer found the brown-tail moth more abundant there than he had ever seen it, hedge rows often being plastered with the winter nests. One such row the writer noted was only a few miles from the border of Holland and within easy flight of the moths to large Dutch nurseries. Belgium has, however, since September, 1909, established an inspection service, applying only to nurseries exporting to America and limited to field examination, twice yearly, of growing stock. While a distinct improvement, the inspection as indicated is still inadequate, as shown by much infested stock still coming to this country under official certificate.

In France, in 1909, Dr. Howard found no governmental inspection system of nurseries. The certificates attached to shipments of nursery stock received in this country from France were signed, as a rule, by men connected with agricultural schools, and probably in the case of most of the certificates the stock had never been seen by the expert. The general infestation of the stock coming from France to this country during the last two years made it abundantly plain that these certificates were absolutely valueless.

Dr. Howard found that nursery stock for export was in many cases grown in the vicinity of hedges and trees infested with the brown-tail moth and gipsy moth and other injurious insects not yet introduced into the United States, and no special precautions were being taken by the nurserymen to prevent the infestation of export stock by injurious insects. The brown-tail moth nests are so characteristic and noticeable that it is only by absolute indifference on the part of French exporters that they are packed for shipment without removal.

As a result of the agitation of 1909, the French exporters promised to take all possible precautions, and the French ministry of agriculture promised to found a governmental inspection service. The Chamber of Deputies, however, failed to pass the inspection law proposed by the ministry of agriculture, and, as already noted, the condition of the "inspected material" of 1910 was no better than in the previous year.

The director of agriculture of France, however, continued to urge the need of a plant-inspection service for export nursery stock, and early in November of 1910 this department was advised, through the Department of State and the ambassador of France to the United

States, of the final establishment of such service. Later the details of the law were communicated to Dr. Howard by Dr. Paul Marchal, who is charged with its execution.

Dr. Marchal's high reputation gives a guarantee of thoroughness, and a great improvement has actually taken place in the condition of the nursery stock coming from France. The rank infestation of 1909–10 has given place to moderate infestation of 1911, but there is still decided room for betterment.

In England Dr. Howard found that, as in France, there was no governmental nursery inspection. The nursery conditions there are somewhat better than in France, but the brown-tail moth and other injurious insects which might easily be imported on nursery stock occur in England. The officials of the Government had the establishment of a governmental inspection service under consideration, and were willing to establish such a service, but stated that the demand for it must come from British nurserymen. An attempt was therefore made by Dr. Howard to get these interests to ask for such service, and, while no action has yet been taken, it seems probable that the English Government will move in this direction.

IMPORTATION OF REFUSE STOCK.

The fact that all the continental countries of Europe have enacted very strict inspection and quarantine laws relating to the entrance into their territories of nursery stock, or other living plant materials, operates very unfavorably for this country, where there is no bar to the entrance of any stock, however worthless, or insect-infested, or diseased. As a result, the United States receives, in addition to fairly good nursery stock brought in by reliable importers, a great mass of refuse stock, imported under the worst conditions, massed in vast quantities in large packing cases, at best in poor condition and often diseased or insect-infested. The United States thus becomes a sort of dumping ground for material which could not find sale in Europe. Much of this worst-quality stock is that referred to elsewhere as being imported by department stores of our larger cities, and also by unscrupulous nurserymen who are careless of their own reputations and the interests of their customers.

NECESSITY OF QUARANTINE LEGISLATION.

The necessity of National quarantine to prevent the general introduction of such dangerous insect pests as those discussed in this bulletin, and also of equally dangerous plant diseases, has long been recognized.

The need of legislation is much increased by the fact that the United States is the only great power without protection from the importation of insect-infested or diseased plant stock. Referring to European powers only, Austria-Hungary, France, Germany, Holland, Switzerland, and Turkey prohibit absolutely the entry from the United States of all nursery stock whatever. Furthermore, our fruits are admitted to these countries only when a most rigid examination shows freedom from insect infestation. Most of the other European countries have strict quarantine and inspection laws, and the same is true of important English and other colonial possessions.

A properly enforced quarantine inspection law in the past would have excluded many, if not most, of the foreign insect enemies which are now levying an enormous tax upon the products of the farms, orchards, and forests of this country. Fully 50 per cent of the insect pests in this country are of foreign origin, and new important foreign pests are becoming established practically every year.

It is of the greatest importance, therefore, that an adequate inspection and quarantine law be passed at the earliest moment.

BRIEF DESCRIPTION OF THE DIFFERENT STAGES OF THE GIPSY AND BROWN-TAIL MOTHS.

THE GIPSY MOTH.

The gipsy moth (*Porthetria dispar* L.) is an European pest which was accidentally introduced into Massachusetts nearly 40 years ago, and has since spread rather slowly, being still confined to the eastern part of Massachusetts and Rhode Island, the southern part of New Hampshire, and to more or less isolated localities in eastern Connecticut and southwestern Maine.

The presence of this insect was first discovered in Boston in 1889, and the State of Massachusetts for a number of years kept up a vigorous effort to exterminate the insect, making large appropriations therefor. This work was abandoned, however, in 1900, but the conditions soon became so bad that appropriations were again made in 1905, and have since been continued annually. In spite of the work of that State, the situation became so serious that the National Government, particularly on the ground of the great danger that these pests would soon spread to other States, was called upon to assist, and since 1907 Congress has been making annual appropriations to aid in the work of control. The amount of this appropriation is now $300,000 annually.

The destructive work of the gipsy moth has been referred to in the foregoing portions of this bulletin. A brief sketch is here given of the life history and habits of the insect with photographs to aid anyone in promptly recognizing it should it appear in new localities.

The gipsy moth has a wide distribution throughout middle and southern Europe, northern Africa, and Asia, including Japan. In a large portion of the Old World range of the gipsy moth it is occasionally abundant and injurious, but as a rule it is held in check by parasites and natural enemies, and in no instance have there been such continuous and disastrous depredations as those exhibited in Massachusetts and more recently in the adjacent New England States.[1]

European outbreaks usually terminate in two or three years. Nevertheless in recent years in Europe and Asia exceptional outbreaks have occurred in which thousands of acres of forests have been completely denuded, and where such denudation has been repeated for two or three years in succession enormous areas have been found covered with dead and dying trees.

The following description of the different stages and habits of the insect is reproduced from Farmers' Bulletin 275 (pp. 12 to 15):

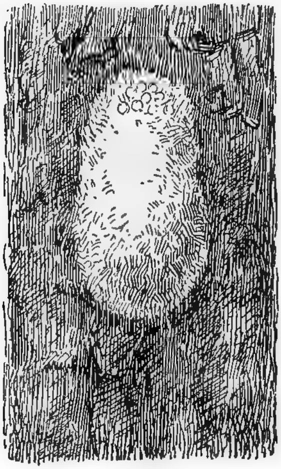

FIG. 1.—Egg mass of the gipsy moth (*Porthetria dispar*). (From Kirkland.)

Description of the different stages of the insect.

The eggs.—The eggs of the gipsy moth are laid in masses (fig. 1) of about 500. The individual egg is minute, about the size of a pinhead, and is salmon-colored when first laid, but turns dark in the course of a few weeks. Each egg mass is yellowish in appearance and seems covered with hair. It is somewhat oval, being one-half of an inch long and about three-fourths of an inch wide. During winter, from exposure to moisture in the atmosphere, it becomes dingy white in color. Egg masses have been found on bark of imported stock during the last two years, and inspectors should be on the lookout for them.

The larva, or caterpillar.—The young larvæ or young caterpillars are dark in color and well furnished with dark hairs. The full-grown larva (fig. 2) is between 2 and 3 inches long, dark brown or sooty in color, with two rows of red spots and two rows of blue spots along the back, and with a yellowish but rather dim stripe between them. The body generally is clothed with long hairs, and sometimes reaches the length of 3 inches.

The pupa.—The pupa (fig. 3) is not inclosed within a perfect cocoon, but the full-grown larva spins a few threads of silk as a sort of support and changes to the pupa, which is dark reddish or chocolate in color and very thinly sprinkled with light reddish hairs.

The adult, or moth.—The male moth (fig. 4) is brownish yellow in color, sometimes having a greenish-brown tinge; it has a slender body, well-feathered antennæ, and a wing expanse of about an inch and a half. The forewings are marked with wavy zigzag darker lines. It flies actively all day as well as by night.

The female moth (fig. 5) is nearly white, with slender black antennæ, each of the forewings marked with three or four zigzag, transverse, dark lines, and the outer border of both pairs of wings with a series of black dots. The body of the female is so heavy as to prevent flight.

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[1] For a more detailed account of the gipsy moth, see Farmers' Bulletin No. 275 (1907) and Bulletin 87 (1910), Bureau of Entomology, U. S. Department of Agriculture.

Seasonal History.

The moths emerge from the pupæ from the middle of July to the middle of August, the date varying considerably according to the season. After mating they live but a short time, and the female dies after depositing her eggs.

The eggs are laid therefore in July and August. They are deposited by the moths on the trunks of the trees upon which the caterpillars have lived, and in fact usually in the vicinity of the place where the female has transformed. The caterpillars before transforming frequently crawl for some distance from the trees upon which they have been feeding, and it therefore happens that the egg masses will be found on fences and in all sorts of protected situations in which the caterpillars hide during the day. The crevices in stone fences often contain very many of these egg masses, and knot holes in old trees will also contain many which would not at first be discovered. The egg masses are found also in hollow trees, in crevices under rough bark, on shrubbery, on buildings, in woodpiles, in barrels, in boxes, and among rubbish in dooryards. The moths seem to choose the inner or lower surface of an object upon which to lay their eggs, and therefore egg masses are placed out of sight perhaps as often as in sight.

The eggs hatch about May 1, and the young caterpillars begin immediately to feed, usually upon the lower surfaces of the leaves. As they grow they cast their skins several times, and as they become larger they feed only at night, hiding during the daytime, usually in clusters on the shady side of tree trunks, beneath large limbs, in holes in trees, under loose bark, and in fact under any near-by shelter. It is the habit of most of them to descend before daybreak upon the trunks of the trees and to seek for such shelters as those just indicated, returning after nightfall to resume their nocturnal feeding.

The larvæ usually become full grown about the 1st of July, and then transform to pupæ. The pupæ are found in the same situations as those we described for the egg clusters, but are found also in the foliage of trees and shrubs.

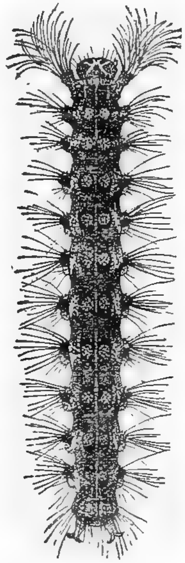

FIG. 2.—Full-grown caterpillar of the gipsy moth. Natural size. (From Insect Life.)

How the Insect Spreads.

As indicated above, the bodies of the females are so heavy as to prevent flight. Therefore the insect must be principally distributed while in the caterpillar or larval condition. The caterpillars are active crawlers, but as a rule do not migrate from the localities where they were born except when food is scarce. When young, and when there is hardly enough food, the larvæ spin down from trees by means of silken threads and often alight upon vehicles of one kind or another, and are thus carried often for great distances from the place of birth. Trolley cars, carriages, automobiles, and bicycles are thus means of transportation almost unlimited in their possibilities. The caterpillars often crawl upon vehicles which happen to stand for any length of time in an infested locality, and thus may be carried great distances. Sometimes even pedestrians aid unwittingly in this distribution, since the caterpillars may drop by their threads upon the garments of a person passing under an infested tree.

The species may be transported, too, in the egg stage on nursery or ornamental stock, as already noted, and it has been shown that the egg clusters are laid upon many different kinds of objects. Cord wood stacked and piled may be carried away in the autumn bearing many egg masses, and, if not burned before summer, larvæ may issue in a new locality. The same may be said for lumber piles near infested trees. Freight cars may have been sidetracked near an infested place long enough to permit laying of the eggs upon them.

It is by these methods that the comparatively rapid spread of the insect previously noticed, during the years 1900–1905, is to be explained.

Damage to Plants.

The larva of the gipsy moth feeds upon the foliage of practically all orchard trees, all shade and ornamental trees, all out-of-door shrubs, and all forest trees. Not only are the deciduous forest trees stripped, but the coniferous trees as well. In June and July patches of forests in the infested territory are stripped of every green leaf and the trees appear as bare as in winter. After several such consecutive strippings, deciduous forest and shade trees are killed, but with a coniferous tree, such as a pine, hemlock, or spruce, one complete stripping will cause death. It is this fact which makes the gipsy moth so much more serious a pest than the brown-tail moth, and the loss which will result from its spread into northern New England will be very great, owing to the enormous coniferous forest interests in that part of the country.

In cities and towns the insect does damage not only by destroying all vegetation, but by swarming in numbers upon and about houses, frequently entering them. It has been the experience in eastern Massachusetts that where a locality becomes thoroughly infested the value of real estate rapidly depreciates, and it becomes a matter of difficulty to rent or sell property.

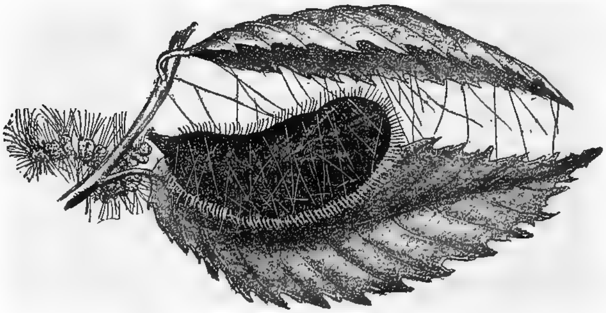

FIG. 3.—Pupa of the gipsy moth. Natural size. (From Insect Life.)

Among its food plants the gipsy moth caterpillar seems to prefer apple, white oak, red oak, willow, and elm, but those who have studied it most carefully in Massachusetts say that it will on occasion devour almost every useful grass, plant, flower, shrub, vine, bush, garden, or field crop that grows in the State.

THE BROWN-TAIL MOTH.

The brown-tail moth (*Euproctis chrysorrhœa* L.) was imported by a florist in Somerville, a suburb of Boston, about 20 years ago, probably on roses from Holland or France. Its presence was not discovered until 1897, when it had already gained such headway that extermination was out of the question. Since 1907 it has rapidly spread, and its range now includes much of the coastal area of New England, including eastern Rhode Island, the eastern half of Massachusetts, the eastern half of New Hampshire, and the southern half of Maine. Both sexes are strong fliers, and the prevailing winds during the flying season (July) have carried the insect northward and eastward, rather than southward and westward. Moths of this species have been taken as far away from Boston as St. Johns, New Brunswick.

This insect is a very serious enemy of orchard, forest, and shade trees and all ornamental shrubbery. In Europe it has a wide distribution, extending from England to the Himalayas, and as far north as Sweden and as far south as Algeria. It is a well-known orchard pest, and for many years laws have been operative in Europe requiring the property owners to clear their trees of the hibernating nests of this insect in winter.

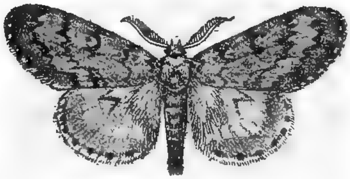

FIG. 4.—Male gipsy moth. Slightly enlarged. (From Insect Life).

The damage to trees and shrubs by this insect is often very severe. It has a special liking for pear and apple, but has a recorded list of over 80 different food plants. Thousands of fruit trees in the vicinity of Boston have been killed by this insect, and serious injury has been done to woodlands and forests, not, however, equaling the damage by the gipsy moth. It does not seem to attack coniferous trees.

One of the most serious results of the presence of the brown-tail is the poisoning of human beings by the hairs shed by the caterpillars, discussed in an earlier paragraph of this publication (p. 11).

The following description of the different stages of the insect and its seasonal history is taken from Farmers' Bulletin 264, which gives a general account of this pest, with general methods of controlling it.[1]

Description of the Different Stages of the Insect.

The eggs.—The eggs of the brown-tail moth are small and globular, and are laid in masses on the underside of leaves in the latter part of July. The egg masses are brown in color and are covered with hair, each mass containing about 300 eggs. They are much smaller than the egg masses of the gipsy moth, with which they are most likely to be confused, and average about two-thirds of an inch in length by about one-fourth of an inch in width. They are thus elongate in form, and are convex.

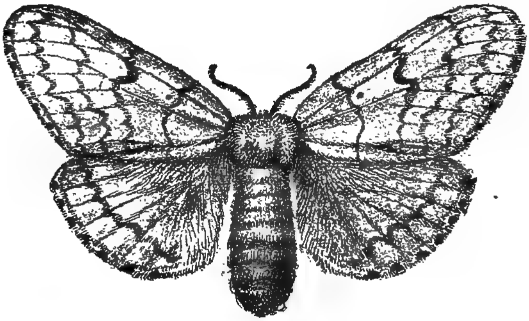

FIG. 5.—Female gipsy moth. Slightly enlarged. (From Insect Life.)

The larva, or caterpillar.—The full-grown larva (fig. 6 at right) is about 2 inches long, reddish brown in color, with a broken white stripe on each side and two red dots on the back near the hind end. It carries also patches of orange and is covered with tubercles bearing long barbed hairs. The tubercles along the back and sides are covered with short brown hairs in addition to the longer ones, which give the tubercles when magnified an appearance like velvet. The head of the larva is pale brown with darker mottlings.

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[1] For a full account of the brown-tail moth see Farmers' Bulletin 264 (1906) and Bulletin 87 (1910), Bureau of Entomology, U. S. Department of Agriculture.

The young larvæ are of a blackish color covered with reddish brown hairs. The head is jet black. Close examination will show projecting from the back of the fourth and fifth abdominal segments a large tuft of reddish brown hairs, and on the middle line of the ninth and tenth segments is an orange or reddish tubercle which may be withdrawn into the body. After the second spring molt the larva is about three-eighths of an inch long, the yellow markings on the body are more apparent, and the brown tufts on the back less prominent, while the band of white dashes along the sides, characteristic of the full-grown larva, is noticeable.

The pupa.—The full-grown larva spins a cocoon of grayish silk, which is very loose in its construction and is so far from being compact that the pupa may be readily seen through it. The pupa itself is about five-eighths of an inch long, dark brown in color, with a conical spine at the end of the abdomen bearing a cluster of minute hooks at the tip. Smooth, yellowish brown hairs are found scattered over the abdomen and the top of the thorax.

The cocoons are apparently spun by preference among the leaves at the tips of branches, and often a dozen or more larvæ will spin a common web within which each individual forms its own cocoon and transforms to pupa. The cocoons are also found under fences and beneath the edges of clapboards. Mr. Kirkland has seen a mass of cocoons nearly 2 feet across in the cornice of a house in Somerville.

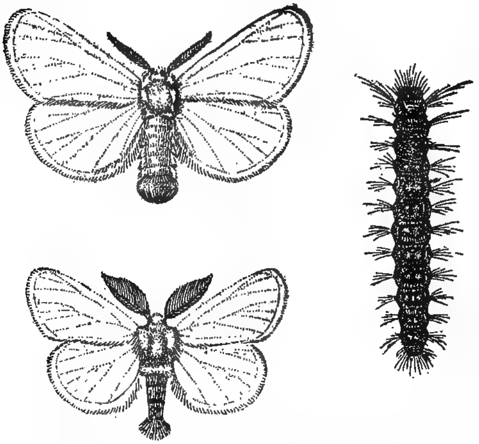

FIG. 6.—The brown-tail moth (*Euproctis chrysorrhœa*): Female moth above, male moth below, larva or caterpillar at right. Slightly enlarged. (From Howard.)

The adult, or moth.—The moths (fig. 6, at left) are pure white, the end of the abdomen being brownish, and both sexes bear at the tip of the abdomen, more conspicuously with the female, a tuft of brown hairs, almost globular in form, from which comes the name brown-tail moth. It is the only moth occurring in America to which this description applies, and is therefore unmistakable. The female expands about 1½ inches, and the male is smaller.

Seasonal History.

The moths fly in New England from the 1st to the 20th of July, the time varying with the condition of the season. In 1898 the height of the flying season is said by Fernald and Kirkland to have been July 16, in 1899 July 8, and in 1902 July 14. It is a night-flying insect, and only a few are ever seen on the wing in the daytime. Soon after sunset a few begin to fly, the number increasing as it grows dark, and from 10 o'clock to midnight they swarm to the greatest extent. They are strong flyers, and are attracted to light. So great have been their numbers in the infested region that the sides of red brick buildings near electric lights have appeared perfectly white. It is at this time that the great spread of the species occurs, and the reason that the direction of the spread has been greatest toward the northeast has been the fact that the prevalent night winds at that time of the year seem to have been from the southwest. Aside from actual flight, the species has spread by being carried in the moth condition on railway trains and on vessels. Captains of vessels have reported that the moths have alighted upon their ships in great numbers in the vicinity of Boston along toward midnight on several occasions, and the introduction of the species at more than one seaport in Maine has been by means of vessels coming from the infested district rather than by direct flight. Of course, the brown-tail moth is carried in the caterpillar stage, just as is the gipsy moth, upon vehicles of different kinds passing through the infested region and upon the persons of pedestrians as well. In late May, 1906, the writer, in company with three other persons, walked through the woods in a region not far from Boston, and although the most careful efforts were made by each of us to pick the caterpillars from the clothes of the others, an hour or two afterwards, and many miles away by automobile, still others were found under the upturned trousers and lapels of coats and in other hidden places about garments.

The eggs are laid by the moths soon after the flight begins, say in the latter part of July. They hatch during August and the young larvæ feed in clusters on the upper surface of leaves, skeletonizing them and causing the foliage to turn brown as if blighted. At first they feed upon the leaf which bears the egg mass, but soon wander to others, returning at night to the original leaf. When first hatched they are about one-twelfth of an inch long, and in five to six days shed their skin, increasing in length to one-fifth of an inch.

Later the second molt occurs, although this sometimes does not take place until autumn within the winter web. Along in September they begin to spin their winter webs by drawing together a number of leaves with silk, and in each of these nests a large number of caterpillars stow themselves away for the winter. These webs or nests, composed of leaves and silk, will average from 5 to 6 inches in length, and each will contain 200 or more caterpillars. The caterpillars feed until cold weather, and then all enter the web and close the exit holes. They are then about one-fourth grown.

These winter webs (fig. 7) of the brown-tail moth are very characteristic, and there are practically no other insect structures common upon trees which may be mistaken for them. There are certain old webs of native species which might possibly, by the untrained eye, be considered to be those of the brown-tail moth, but these are empty in the winter time. Any web of this character and general size found during the winter which contains young caterpillars in any number is the web of the brown-tail moth.

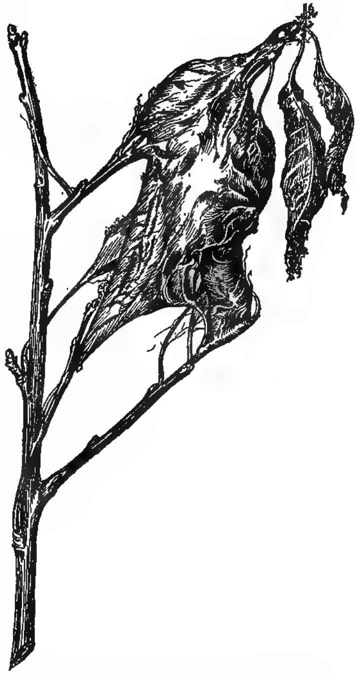

FIG. 7.—Winter nest of the brown-tail moth, containing 300 or 400 young caterpillars. (Original.)

The following spring, as soon as the buds begin to appear upon fruit trees, these young, one-fourth-grown caterpillars issue from the overwintering nests and attack first the buds and blossoms and later the foliage. Apparently half starved by their long hibernation, they come out with voracious appetites, and the amount of damage done by them at this time is extraordinary. Old trees may lose all their buds, or, if the leaf buds and blossom buds burst, the foliage itself may be entirely destroyed at a later date. The growth of the larva is rapid, and it reaches full size and begins to spin its cocoon during the last half of June, transforming to pupa and remaining in this condition for approximately 20 days.

Damage to Plants.

As just indicated, the damage to trees and shrubs may be very severe. The list of food plants is very extensive. While there seemed at first to be a preference for pear and apple, the larvæ were found to feed also upon the stone fruits, as well as upon the elm, maple, and several species of oak. Of late years there has been a very extensive infestation of scrub oak and of the larger trees of the genus Quercus. In fact, the caterpillars feed generally upon all deciduous trees, on many shrubs, and even upon herbage. A list of over 80 different food plants was published by Fernald and Kirkland in 1903. Thousands of fruit trees in the vicinity of Boston have been killed by this insect. Injury to woodlands and forests has not been as severe as that accomplished by the gipsy moth, and coniferous trees do not seem to be attacked, but the damage to oak, maple, and elm in the wooded region has been sufficient to cause the forests to appear brown in June in places, and complete defoliation for a series of three or four years has brought about the death of many trees. Even where the tree survives, its growth has been checked, and there is a timber loss.

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O

THE "WILT DISEASE," OR "FLACHERIE,"

OF

THE GYPSY MOTH.

BY

WILLIAM REIFF,
BUSSEY INSTITUTION OF HARVARD UNIVERSITY.

UNDER THE DIRECTION OF

F. W. RANE, STATE FORESTER.

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INTRODUCTORY.

Anything that offers promise of being effective in our warfare against the gypsy moth is hailed with delight by our Massachusetts people.

It is with pleasure that the State Forester is able to offer this publication, setting forth the work with the " wilt disease," or " Flacherie," of the gypsy moth, which has been carried on during the past two years by Mr. William Reiff, under the supervision of Prof. W. M. Wheeler of the Bussey Institution of Harvard University. Professor Wheeler's co-operative interest in the moth-suppression work in the State is highly appreciated by the State Forester, and the results shown in this bulletin will prove, we are sure, of great interest generally.

This bulletin is a companion, in a way, to that issued on parasites, in that it is another method of attacking our foe. We desire to have as many strings as possible to our bow in fighting this pest. That this " wilt disease " is a most hopeful remedy there is little question. We anticipate carrying on even more extensive work with it the coming season.

Upon reading this bulletin it will be readily apparent that any one can easily assist in furthering this work at little, if any, expense; and it is to be hoped that many will not only acquaint themselves with the methods employed, but experiment on their own initiative. If the State Forester can assist you in any way do not hesitate to call upon him.

ACKNOWLEDGMENTS.

The experimental work and writing up of the data in this bulletin was done by Mr. William Reiff of the Entomological Laboratory of the Bussey Institution of Harvard University.

The State Forester decided that the work undertaken by Mr. William Reiff during the season of 1909 was well worthy

of being continued upon a much larger scale, and co-operative plans were happily agreed upon with Dr. Wheeler, with the results as outlined in this bulletin.

Besides Professor Wheeler and Mr. Reiff, there are the field agents and local superintendents of the regular moth staff, who made it possible to get results. To these we are also under obligations for their loyal support and co-operation.

F. W. RANE,
State Forester.

Boston, Mass., March 21, 1911.

THE "WILT DISEASE," OR "FLACHERIE," OF THE GYPSY MOTH.[1]

I. Caterpillar Diseases in General.

The production of diseases is one of nature's methods of quickly checking the overproduction of living things. Animals, including man, and plants all have their own specific infectious diseases, which usually appear whenever a species becomes so numerous that it menaces the prosperity of the coming generations. In the animal kingdom the possibility of overproduction is especially apt to occur in insects, since they form by far the largest portion of the world's fauna, and have a high rate of reproductivity. Insects, small though they are individually, form in their totality an immense mass of living matter. Of this mass we can get only a slight conception, even when we consider that insects are everywhere present, not only as a few scattered individuals, but in such enormous numbers that they constitute, as it were, a world in themselves. We may say without hesitation that among all the conditions which arise from and are caused by animals, there is none more widely distributed, more many-sided and which interferes more deeply with life on our planet than that which is brought about by insects. As Graber says: —

> Man may unwisely neglect these creatures — as he does many things; but their power for evil crushes him the more; indeed, it may destroy him if he persists in his neglect.

Now, such a power may be checked by nature by one of the most efficient means which she possesses, — the infectious diseases.

Owing to the profound influence which insects exert upon us and our culture, attention has been drawn to their diseases. A close study has been made of some of these; especially of those known to occur in the silkworm (*Bombyx mori*) and in the "nun" moth (*Psilura monacha*), which latter destroys the forests of Central Europe.

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[1] Contributions of the Entomological Laboratory of the Bussey Institution, Harvard University, No. 36.

The first scientific knowledge which we have of caterpillar diseases we owe to the valuable investigations of the French scientist Pasteur. Since his time many other investigators have been engaged in this study, among them the Germans Standfuss and Emil Fischer, the Italians Verson and Bolle, and the Americans Snow and Forbes. By their experiments and investigations we are now able to recognize the character of the more common caterpillar diseases.

We may mention some of those diseases with which the lepidopterist will come in contact in the course of a few years.

A very frequent disease of caterpillars is the *common diarrhœa,* which is produced in most cases by too juicy or too wet food. This is shown by the unusually wet excrement, the fluid part of which is green. If the disease is of longer standing, the excrement does not cling together, but is voided as a pulpy mass, in which the single vegetable particles swim around undigested. This disease in itself is not dangerous, since it is not infectious, but it may prepare the way for the attack of other infectious diseases, which will be mentioned further on.

In another disease, which has no popular name as yet, and which I shall call *bead disease,* the excrement masses hang from the body like a string of beads. This intestinal disease is probably due to unhealthy food, but the specific cause has not been determined. Apparently this disease, too, is not infectious.

Of much greater importance is the disease known as *muscardine.* This is really a collective name for a series of fungous diseases, which convert the infected caterpillar in a short time into a stiff, swollen mass, with the skin invested with a grayish-white coating. Very hairy caterpillars are especially susceptible to muscardine, but in extremely wet years even smooth caterpillars suffer from fungous diseases. It is easy to determine whether muscardine is present in a given locality because the diseased caterpillars crawl toward the exposed tops of grass blades, poles or stems, and remain there after death, thus becoming visible for a considerable distance. On a trip which I made in June, 1910, to Raymond, N. H., I saw thousands of brown-tail moth caterpillars dead from muscardine, and commonly hanging in this characteristic manner. Since these fungous diseases are extremely infectious, and propagate with incredible swiftness, and since healthy caterpillars are much inclined to gnaw at dead ones, the artificial production and propagation of muscardine has been hopefully considered during the last few years as a means of destroying the brown-tail moth.

There are two fungi, especially, which are responsible for the death of most caterpillars; these are *Botrytis bassiana* Bals and *Entomophthora aulicae* Reichhardt. Experiments with fungous diseases of the brown-tail moth are being conducted by Mr. A. T. Speare, under the direction of Dr. R. Thaxter of Harvard University.[1]

The *pébrine* or *pebrina,* which has become so notorious through the great damage it has caused to the silk industry, is the caterpillar disease which has been studied so far most thoroughly. Caterpillars with this disease always have a wet anus, and if they are hairy, the hairs on this region of the body stick together. Smooth caterpillars also change their color considerably; for instance, green caterpillars turn yellowish, and are often mottled with dark, irregular spots; gayly colored caterpillars lose their brilliancy. This disease does not kill in a few hours or days, but the infected caterpillars languish slowly, lose their appetite, and become transparent and ill-nourished. They then shrink more and more, till finally at death only the flabby dry skin remains. Pébrine appears preponderatingly in wet years, and its cause seems to be lack of nourishment. The specific cause, however, the disposition, has not yet been absolutely determined. The carriers of the disease are known under the name *Corpuscoli di Cornalia,* and have been described by Lebert[2] as the fungus *Panhistophyton ovatum* (*Micrococcus ovatus*). Here it might be of interest to cite from a review in "Deutsche Entomologische

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[1] "Seventh Annual Report of the State Forester of Massachusetts, " 1910, pp. 98–101.

[2] "Berliner Entomologische Zeitschrift," 1858, p. 170.

National Bibliothek," No. 3, Jahrg. II., 1911, where it is stated that the botanist Naegeli described the carrier of the pébrine, as early as 1857, as *Nosema bombycis.* This review, moreover, mentions the fact that W. Stempell (38. Jahresber. Zool. Sekt. Westf., Prov. Ver. f. Wiss. u. Kunst, 1909–10, p. 37) has made artificial infection experiments with this parasite, and found that it develops with extreme rapidity and great virulence, not only in caterpillars of the silkworm, but also in caterpillars of several local species of the same family. Thus Stempell reached the conclusion that this susceptibility of the individuals towards the pébrine parasite might be used practically in combating injurious caterpillars. He further mentions that his researches on this and other *Microsporidia* are of biological interest, since it would seem that there must be organisms so minute that they cannot be seen, even with our most modern optical instruments. In several infectious diseases the carriers of the disease have not yet been optically demonstrated, and it may be that these carriers are such small organisms. These little oval shining bodies are now no longer regarded as plant organisms, but as belonging to the *Psorospermii,* a group of Protozoa. Pébrine is extremely infectious, and is carried over, as Pasteur has proved, from generation to generation in the eggs, with increasing destructiveness.

We come now to the last and probably most important of all the common caterpillar diseases, the disease called *Flacherie, Flaccidenza* or *caterpillar cholera,* and in America known also under the name "wilt disease." This disease is characterized as follows: a caterpillar suffering from it soon stops eating, becomes weak and lazy, and usually crawls up on some object, as the trunk of a tree, a fence, a wall, or other vertical surface, where it remains without motion. In a few hours there drops from its mouth and anus a dirty, blackish, foul-smelling liquid; the caterpillar becomes more and more flaccid, one leg after the other looses its support, and finally the creature, reduced to a black skin, hangs dead, still holding on with one or two of its false feet or with the anal claspers. The slightest touch now suffices to break the skin, and a thin, dark, offensive-smelling liquid flows out. Flacherie kills the older more quickly than the younger caterpillars. Young caterpillars, indeed, often live several days before they are killed by the disease. It is not positively known what organisms produce Flacherie. The bodies of caterpillars which have died of this disease show extremely small bacilli, innumerable schizomycetes, and, more particularly, many small strings of micrococci; but which of these micro-organisms, if any, is the real carrier of the disease is still unknown to specialists.[1] To the investigations of Dr. E. Fischer, in Zürich, Switzerland, we owe considerable information regarding the primary causes leading to Flacherie, and the manner in which the disposition to this disease may be induced. He has pointed out that a decrease in the nutritive value of the food of the caterpillars, which induces a disturbance in their metabolism, is the first condition leading to the contraction of the disease. As a result of these disturbances the organisms responsible for the disease immediately find conditions suitable for their growth. One of the main causes of the disease is therefore to be sought in the predisposition of the caterpillars, while the specific infection of Flacherie is to be regarded as coming more or less secondarily; in other words, without this predisposition infection cannot take place, and the predisposition can be brought about artificially by insufficient nourishment.[2] Flacherie seems to be influenced by climate and weather conditions less than any other caterpillar disease. We meet with it both in the old and the new world, in wet, in dry and in normal weather. As a result of its comparatively great abundance and its extremely easy infection, Flacherie has become the "guardian angel" of the Central European forests. When the "nun" (*Psilura monacha*) makes its appearance in some places in Europe in vast numbers, man with his wit and the powerful means at his command is quite unable to stop the destruction, but Flacherie always comes to his assistance. Although this disease has been much studied, it has not yet been positively established whether it is hereditary or not. There is at present no argument that can be brought against the heredity of the disease, while there are some important facts which indicate its heredity. These will be considered later.

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[1] Very recently C. Sasaki, in Tokyo, Japan, found that there were also polyhedral corpuscules present in caterpillars which were sick from Flacherie ("Deutsche Entomologische National-Bibliothek," Jahrgang II., 1911, No. 1, Referat). Since polyhedric corpuscules, however, are found chiefly in caterpillars which have been infected by the pébrine, a close relationship of these two diseases is highly probable.

[2] See Fischer's detailed accounts in the "Biologisches Centralblatt," Band XXVI., No. 13-16, Leipzig, 1906.

II. Résumé of Some Experiments with Flacherie in 1909.

Fischer called attention, in his excellent paper, already mentioned, to the manner in which Flacherie can be artificially developed. He says that the disposition to the disease is secured by giving the caterpillars food which has been placed in water and renewed only every three or four days. This treatment apparently causes an injury to the leaf protoplasm, due to the presence of too much water, and there is a concomitant increase in the acidity of the leaves.[1] If, now, a caterpillar eats such leaves, the alkalinity of its digestive fluid, which is very strong in healthy individuals, decreases, and in this manner the first susceptibility to the disease is given. Before the visible outbreak of Flacherie, Fischer could recognize as an early symptom a characteristic sweet odor in the breeding cages, which could be compared best to that of somewhat withered lilac blossoms. Whenever this odor was noticeable Flacherie soon made its appearance, and as it progressed the odor increased proportionately. Fischer recommends the artificial production of Flacherie among the caterpillars of the "nun" ("die Nonne" of the Germans) by intentionally giving the larvæ this kind of food as soon as an abundance of the pest is noted in any particular locality.

Bearing in mind the close relationship existing between the "nun" and the gypsy moth, I attempted during the summer of 1909 to put Fischer's conclusions regarding the artificial production of the wilt to a practical test. These experiments were published in detail in the entomological journal "Psyche," Vol. XVI., No. 5, October, 1909. There appeared also a German translation of the paper in the "Societas Entomologica," Jahrgang XXIV., pp. 178–181, Zürich, Switzerland. The main facts in these experiments are here noted. Up to 70 per cent. of the caterpillars were killed by artificially produced

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[1] See the experiments which Sasaki performed on mulberry trees in Japan, "Zeitschrift für Pflanzenkrankheiten," XII. Band, Jahrgang 1902, 4. Heft, pp. 203–226; 5. Heft, pp. 258–278.

Flacherie, while all caterpillars which were kept apart for control remained healthy. From these results I was therefore led to believe that the artificially produced Flacherie might be utilized as a valuable aid in the destruction of gypsy moth caterpillars. If the disease appears in nature during normal weather conditions, the caterpillars are in most cases almost full grown when attacked; but the farther the weather conditions of the year differ from the normal, the earlier in their life will the disease affect them. The fact that I succeeded in rendering the caterpillars susceptible to the wilt before the third molt suggested that this may be of importance in the practical use of the disease, since by artificially inducing Flacherie, relief might be had weeks sooner than happens in nature.

Better to understand the conclusions drawn from the last experiment, which was performed on trees on which a considerable number of gypsy moth caterpillars occurred naturally, the following account is given: A group of oak and another of willow trees were infested with about 5,000 caterpillars each. Shortly before their fourth molt, upon each of these two groups of trees 100 sick and 50 dead caterpillars were destributed. The disease spread with amazing rapidity, and even on the following day many freshly killed caterpillars could be counted. By the time of pupation about 4,000 caterpillars on each group of trees had succumbed to the disease. Two conditions which did not enter into my previous experiments united to cause this unusual result. In the first place, the two groups of trees had been badly infested and injured by gypsy moth caterpillars the previous season, as was evidenced by the unhealthiness of the leaves during the summer of 1909, and the caterpillars had probably become predisposed to the disease on account of the resulting decrease in the value of their food. As a second very important factor may be mentioned the dry weather, which by its desiccating effect upon the leaves served to render the food for the caterpillars still less nutritious. Hence, from the beginning there was a decreased vitality in the tissues, and digestion was early disturbed. In short, the caterpillars were already very susceptible to the disease at the time I introduced it among them, and conditions were therefore most suitable for the spread of the wilt. Always in the places that have been injured by gypsy moth caterpillars in previous years, there is a predisposition on the part of caterpillars of the following year toward Flacherie. The heavy defoliation checks the normal metabolism of the attacked vegetation, which causes a weak and sickly development of the shoots, and these therefore do not furnish the caterpillars sufficiently wholesome nourishment. It should be remembered that these facts, in the long run, mean a self-protection of the vegetation. If at this time dead and sick material is introduced among the caterpillars in such a locality, the organisms of the disease will act readily upon the individuals present. Infection will take place even in cases where a locality is badly infested by the caterpillars for the first time, because one can always find a large number of weak and therefore susceptible specimens. Then, as the disease progresses, it acquires such virulence that even the previously healthy specimens become infected.

In the article mentioned I called attention to other ways in which the caterpillars advance the infection among themselves, that is, during the resting period, during the feeding time, etc., and how easily the disease may be carried over by the caterpillar to its pupal stage. The great probability of an economic value in Flacherie for destroying the gypsy moth was suggested, but it was thought that the experiments of only a single year had better not be taken as a comprehensive method for the practical use of the wilt, and that further experiments should be undertaken on a larger scale to substantiate the obtained results.

III. Flacherie Experiments in 1910.

A. General.

In the spring of 1910 the author was requested, by the State Forester of Massachusetts, to make similar experiments on a large scale in different parts of the State.[1] These experiments were undertaken with the help and kind encouragement of Prof. W. M. Wheeler. I would also express my indebtedness to all those from whom I have received advice and actual assistance. My thanks are also due to State Forester Frank W. Rane and Assistant Forester L. H. Worthley for much help; and to their division agents, Norman Souther of Bridgewater, and Francis C. Worthen of Georgetown, and to Mr. H. P. Richardson, local moth superintendent of Concord, for their support in the field work. Last but not least, I owe, through correspondence, several valuable hints to Dr. E. Fischer, Zürich, Switzerland, who, through his investigations on insect diseases, is to be regarded the proper instigator of these experiments.

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[1] *Cf.:* "Sixth Annual Report of the State Forester of Massachusetts," 1909, p. 86.

In the beginning of the work each of the division agents was asked by letter to suggest convenient localities in which to conduct the experiments. Three of the division agents stated that they had no suitable places in their districts. In the remaining divisions 29 places were chosen, but at the end of my investigations unfortunately 13 of these could not be used, since some of the local moth superintendents had not followed instructions, and other places had been sprayed with arsenate of lead. Isolated forest districts, varying from small areas to several acres, were chosen for the experiments. The isolation was for the purpose of making easier a control of the place, since in such a locality an eventual increase or decrease of the caterpillar mass by migration was less probable. The local superintendents of the different places were instructed not to use any artificial means for destroying caterpillars in the selected woods. I was, however, obliged to use some localities in which, during the preceding winter, some of the egg clusters had been killed by creosote. According to the size of the various places, the local superintendents were requested to collect a corresponding mass of gypsy moth caterpillars shortly before their second molt. These amounted to from 50 to 100 individuals per acre. Where many egg clusters were present but few caterpillars had to be collected, and *vice versa.* Hence, the number of caterpillars to be collected was decided in advance for each locality. The reason for this is that an infection spreads more easily and rapidly in a heavily infested district than in places less damaged by caterpillars. In a badly infested forest of 10 acres or more the average number of caterpillars to be collected was placed at less than 50 specimens per acre, since the disease spreads best in such localities.

The local superintendents had been instructed to feed the collected caterpillars daily with oak leaves, or with apple leaves where oak leaves could not be secured. These leaves were not to be removed from the twigs, and were to be placed in water for at least four days before feeding. A special emphasis was laid on not giving as food leaves of trees which had been sprayed with arsenate of lead. As breeding cages common wooden boxes were used, to which the entry of air was provided for by means of gauze coverings. Further, the local superintendents, who were not familiar with the wilt, were taught the character of this disease and its manner of appearance, and were instructed to communicate with me at once on the first appearance of Flačherie in their breeding cages. The local superintendents were asked to attend to this part of the work, since at that time it was not convenient to rear several thousand gypsy moth caterpillars in one place, and also in order that their interest might be awakened in the experiments.

As soon as the wilt was determined to be present in a brood the whole material was transplanted upon the previously chosen places, with the help of the respective superintendents. This was done as follows: a piece of clean cloth, burlap, for instance, about 2 feet long by 1 foot wide, was hung in dense foliage between the limbs of a tree, or from one tree to another close by (Fig. 1). In this hammock-like bag were placed, besides the dead and still living caterpillars of the brood, also all food remaining in the breeding cage, since such remains might also be supposed to contain organisms of the disease. No means were used to prevent the escape of the sick but still crawling caterpillars, in order that they might disseminate the organisms.[1] Where possible, the bag with the material was hung about 6 feet or still higher from the ground, in order that the wind might aid in the spread of the disease. In planting the diseased material the direction of the prevailing wind of the season was taken into consideration. For instance, in localities which had prevailing east winds the infected material was exposed near the eastern border of the forest, but still inside of it, so that the wind, before reaching the larger part of the wood, was forced to strike first the center of the diseased area. It may be mentioned that in some cases, where no convenient cloth was at hand, the breeding cages themselves with the material, after the removal of the cover, were hung between limbs. No difference was observed in the results. The infected material was planted in most of the localities at a time when most of the caterpillars in the field were undergoing the third molt. The respective ages of the caterpillars will be mentioned under each experiment.[1]

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[1] That this is the case is proved by some experiments which I shall consider particularly later, where only sick caterpillars were transplanted, but no dead caterpillars.

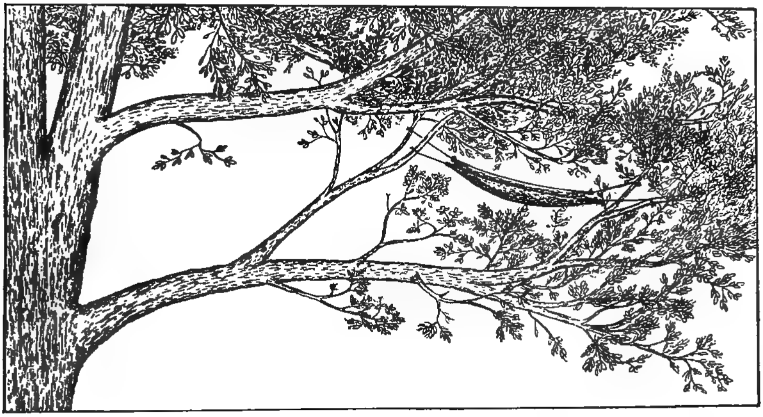

Fig. 1.— Method of hanging hammock in tree.

It was important to select places which gave the best guarantee for the health of the growing caterpillars; hence, special attention is called to the fact that in the experimental localities no disease is known to have occurred among the caterpillars of previous years.

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[1] I had always planned to plant the disease as soon as it made its appearance in one or the other of the broods. This was, however, frustrated on several occasions by various circumstances. For instance, some local superintendents did not notice the Flacherie till after the disease had prevailed for several days. It was, further, not always possible for me to depart immediately upon receiving a communication concerning the outbreak of the disease. It was also almost impossible for one man to transplant the infected material to all the chosen places during the short time in which the gypsy moth caterpillars were in the third or beginning of the fourth stage. This is the reason why in some localities the disease was planted later, although the caterpillars were already beyond the third molt.

After the eggs were laid in the autumn of 1910 all localities were carefully inspected, and the number of the fresh clusters was determined as nearly as possible. For examination of the single eggs, five clusters, when possible, were collected from each locality. Five clusters from a place in the western part of Concord, Mass., served for control. These eggs must be considered as normal because they come from a place in which positively no disease whatever has occurred. In collecting clusters for examination the first five found were taken; and were not taken at random.

Every single egg of all these clusters was examined microscopically. This, it is true, required very much time, but it was nevertheless indispensable. The eggs were separated into three kinds: first, those that showed no signs of development of the embryo (empty or unfertilized eggs); second, those in which the more or less developed embryo had been killed before its complete development; and finally, those which showed a perfectly developed embryo (normal and supposedly living eggs). In every case in which the egg could not be absolutely assigned to the second series it was counted with the third series.[1]

In the details of all the work everything which seemed to suggest the economic value of the wilt has been purposely regarded from the most unfavorable standpoint, for the purpose of meeting any objections. When estimating the egg clusters from the selected localities there was always present either the division agent or the local superintendent, and at that time written notes were made of these estimates before the introduction of the disease. In the spring we made the lowest possible estimate on the number of clusters present, while with the second estimate in the autumn, after the disease had produced its effect, the fresh clusters were estimated as liberally as possible.

The average which resulted from the examination of the single clusters must not be taken as absolutely fixed, since the small number of the clusters examined admits of a variation from the mean in both directions. The main purpose of the experiments, however, was not to make mathematically exact calculations, but to find out in what manner and to what degree the gypsy moth may be infected by the wilt. For these purposes the calculations made should be sufficient, and the figures given will not be far from the real average.

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[1] The eggs of the control clusters could all be distributed with exactitude into the respective series.

As to the control experiment, the average of eggs in a normal cluster was found to be 437. I am not aware that the eggs of a large series of normal clusters have ever been counted in order to establish an accurate average. In published reports the average of eggs in a normal cluster is stated as "400 to 500."

Control Experiment, Concord, Mass.

Five clusters were taken in the western part of this locality, where there certainly did not occur any disease among the gypsy moth caterpillars. These clusters, therefore, must be regarded as normal. The microscopic examination of the eggs of these clusters gave the following results: —

Cluster 1.

Unfertilized eggs,	1	= .73 per cent., or about 1 per cent.
Eggs with dead embryos,	3	
Eggs apparently alive,	543	=99.27 per cent., or about 99 per cent.
Total,	547 eggs.	

Cluster 2.

Unfertilized eggs,	–	= .47 per cent., or about .5 per cent.
Eggs with dead embryos,	2	
Eggs apparently alive,	424	=99.53 per cent., or about 99.5 per cent.
Total,	426 eggs.	

Cluster 3.

Unfertilized eggs,	3	= 1.74 per cent., or about 2 per cent.
Eggs with dead embryos,	4	
Eggs apparently alive,	395	=98.26 per cent., or about 98 per cent.
Total,	402 eggs.	

Cluster 4.

Unfertilized eggs,	1	= .93 per cent., or about 1 per cent.
Eggs with dead embryos,	3	
Eggs apparently alive,	424	=99.07 per cent., or about 99 per cent.
Total,	428 eggs.	

Cluster 5.

Unfertilized eggs, ...	–	} = .79 per cent., or about 1 per cent.
Eggs with dead embryos, .	3	
Eggs apparently alive, . .	377	=99.21 per cent., or about 99 per cent.
Total, ...	380 eggs.	

The average of these 5 clusters is as follows: —

Dead eggs, ...	4	= .92 per cent., or about 1 per cent.
Eggs apparently alive, .	433	=99.08 per cent., or about 99 per cent.
Total, ...	437 eggs.	

The results of this control experiment are used in estimating the departure from the normal of the egg masses in all the other experiments.

B. The Single Experiments.

Concord, Mass.

Division Agent, Chas. W. Minot; *Local Superintendent,* Henry P. Richardson.

As a suitable place for my experiments, I located, on May 20, 1910, an isolated forest of about 2¼ acres, belonging to the estate of Mr. William Brewster. This place is situated in the eastern part of Concord, about half a mile west of the West Bedford railroad station. The forest consists mainly of oaks about twenty years old and of a group of pines about fifty years old, all mixed with brush; and along the border, especially on the northern part, are birches about ten years old.

According to the local superintendent and to the owner, Mr. Brewster, the gypsy moth caterpillars were quite numerous during the summer of 1909. Both are certain that there was no disease among the caterpillars. We estimated this place to contain about 10,000 clusters of eggs in May, 1910.

On June 6 I received notice from the local superintendent that the wilt had appeared among the caterpillars which he had collected and fed according to instructions. Two days later I went to Concord, and found that some 10 caterpillars were already dead and the others were apparently very sick, as they remained motionless even when irritated. The superintendent had begun to feed the caterpillars on May 26, and had noticed the first dead specimen on June 5. Accordingly, he had succeeded in developing the wilt artificially in the course of eleven days.

With the assistance of the local superintendent the whole breeding material was immediately exposed in the western part of the selected forest. The distance from the ground to the material, which was hung between the limbs of a tree, was about 15 feet. The largest number of gypsy moth caterpillars in this locality were at this time in the third molt, or about to pass into this molt. The wilt soon spread over the whole forest, as was seen during occasional visits to the place by Mr. Richardson, Mr. Brewster and myself. On Sept. 7, 1910, the fresh egg clusters were estimated by the local superintendent and myself to amount to about 5,000. Often 4 or 5 of these clusters together would not make more than 1 normal cluster; the actual number of eggs was thus much less than would have been present in the same number of normal clusters.

The examination of 5 clusters which had been collected Sept. 7, 1910, on Brewster's estate showed the following counts: —

Cluster 1.

Unfertilized eggs, ...	3	= 9.66 per cent., or about 9.5 per cent.
Eggs with dead embryos, .	11	
Eggs apparently alive, .	131	=90.34 per cent., or about 90.5 per cent.
Total, . .	145 eggs.	

Cluster 2.

Unfertilized eggs, ...	2	=7.43 per cent., or about 7.5 per cent.
Eggs with dead embryos, .	9	
Eggs apparently alive, . .	137	=92.57 per cent., or about 92.5 per cent.
Total, ...	148 eggs.	

Cluster 3.

Unfertilized eggs, ...	13	=48.06 per cent., or about 48 per cent.
Eggs with dead embryos, .	49	
Eggs apparently alive, . .	67	=51.94 per cent., or about 52 per cent.
Total, ...	129 eggs.	

Cluster 4.

Unfertilized eggs, ...	1	= 8.64 per cent., or about 8.5 per cent.
Eggs with dead embryos, .	6	
Eggs apparently alive, . .	74	=91.36 per cent., or about 91.5 per cent.
Total, ...	81 eggs.	

Cluster 5.

Unfertilized eggs, ...	—	= 6.76 per cent., or about 6.5 per cent.
Eggs with dead embryos, .	5	
Eggs apparently alive, . .	69	=93.24 per cent., or about 93.5 per cent.
Total, ...	74 eggs.	

Averaging these 5 clusters we have:—

Dead eggs, ...	20	=17.24 per cent., or about 17 per cent.
Eggs apparently alive, .	96	=82.76 per cent., or about 83 per cent.
Total, ...	116 eggs.	

A normal egg cluster contains on an average 433 eggs (p. 20) which are apparently alive. Since the infested locality averages only 96 eggs which are apparently alive per cluster, 4½ clusters are necessary to equal the size of a normal cluster. The number of the fresh clusters, estimated at 5,000, thus has to be reduced to about 1,100 clusters to compare with the 10,000 clusters present in the spring of 1910. The number of apparently vital eggs, therefore, is decreased to about 11 per cent. through the action of Flacherie.

The local superintendent informed me that the disease had also spread into the neighboring forest districts. By an extended walk through about 5 acres of these woods I learned that the wilt had operated in the same manner as in the first locality. He is of the opinion that the number of clusters in this 5 acres has been decreased to about 15 per cent. Adjoining these woods there are about 15 acres of forest, in which the local superintendent found that all egg clusters which had been laid in the summer of 1909, and which had been deposited 1 foot or more above the ground, had failed to produce caterpillars, that is, the eggs had remained unhatched; but the caterpillars had all emerged from those eggs in clusters placed less than 1 foot above the ground. I found that these statements corresponded very closely with the facts. Here and there I noticed a slight exception by occasionally finding either a high-placed cluster from which a few caterpillars had emerged, or I detected close to the ground a cluster from which only a portion of the caterpillars had emerged. These exceptions, however, were insignificant, for they represented in each case hardly more than 10 eggs. I am unable, so far, to find any explanation for this peculiar occurrence. At first I thought that an egg parasite might have exerted its helpful power, but the examination of eggs from several clusters which had remained unhatched showed that almost all eggs contained a fully developed dead embryo, and no signs of a parasite could be found. The moisture of the soil cannot be made responsible, for bordering this forest there is another with exactly the same soil, the same kind of trees and of the same age as the other place, and although these forests are separated only by a very broad road, in the latter wood the caterpillars of almost all egg clusters of 1909 had emerged from clusters that had been placed at any height on the trunks of the trees. There were exceptional cases of clusters, sometimes on the upper, sometimes on the lower part of the trees, from which all caterpillars had not emerged, but there was no evidence of the peculiar condition that characterized the clusters in the place first mentioned. Whether any caterpillar disease has any effect in this occurrence, I cannot now say. The solution of this question may come in the future from careful observations at this particular locality.[1]

An extensive forest in the southwestern part of Concord was visited, in which, according to the information of the local superintendent, the wilt had broken out naturally. The peculiar conditions which we found here require a detailed description of the locality and of the manner in which the disease operated. The largest part of the forest, about 20 acres, is situated upon the ridge of a hill. On the east and west the hill slopes to wet meadows. On the north and south the hill gently passes over into level country, and it is bordered here by broad roads. The principal trees on the ridge of the hill are high pines about sixty to eighty years of age; brush is almost absent. The slopes are covered in large part with young oaks, which are much mixed with brush of different kinds. Now, while the forest of the whole ridge, including the northern and southern slopes, suffered considerably from injuries by gypsy moth caterpillars during the summer of 1910, the eastern and western slopes were exempt from this damage. Soon after the caterpillars had passed the third molt Flacherie made its appearance among those feeding on the pines upon the ridge of the hill. The disease developed here so rapidly that probably all caterpillars were killed, for we were unable, even by careful search in these 20 acres, on Sept. 7, 1910, to find a single fresh cluster. The statement, therefore, seems justified that all caterpillars, at least all the females (100 per cent.), were here killed by the wilt. This very high number, however, was restricted to the forest upon the ridge of the hill. On the first trees of the northern and southern slopes fresh egg clusters were found, and the number of these increased as we went toward the plain. But the inspection of such dead caterpillars as were observed showed that the wilt had also operated in the woods of these slopes. The local superintendent looked here for Flacherie, but it did not appear till the caterpillars were in their last stage. The reason for this behavior of the wilt might be that the ridge of the hill, with its high trees, was much exposed to the effect of the wind, and after Flacherie had once developed it could be spread very rapidly along the ridge. On the northern and southern slopes, however, the wind could not strike so hard, and the spreading of Flacherie toward the plain, therefore, took place comparatively slowly. Upon the eastern and western slopes, on account of the lack of caterpillars, the conditions necessary for developing the wilt were not present.

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[1] Similar observations, where eggs have not hatched, were made elsewhere by different persons connected with the moth work, but no definite observations, as at Concord, were reported.

A map of the place, sketched by Mr. Richardson (Fig. 2), which may aid in understanding the description, is given herewith.

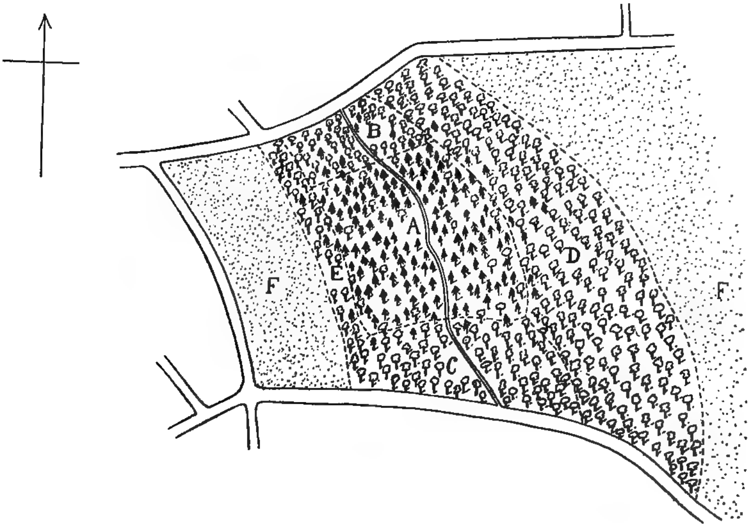

Fig. 2.—Experiment, Concord, Mass. A. Summit of hill, now cleared. B. Northern slope, infested. C. Southern slope, infested. D. Eastern slope, not eaten. E. Western slope, not eaten. F. Meadows.

Five clusters were examined for comparison from the localities in which Flacherie developed naturally. These were collected on a walk through the forest district at the southern end of the hill, and from different trees taken at random. The result was:—

Cluster 1.

Unfertilized eggs, ...	4	=12.59 per cent., or about 12.5 per cent.
Eggs with dead embryos, .	16	
Eggs apparently alive, . .	139	=87.41 per cent., or about 87.5 per cent.
Total, ...	159 eggs.	

Cluster 2.

Unfertilized eggs, ...	2	= 5.30 per cent., or about 5 per cent.
Eggs with dead embryos, .	6	
Eggs apparently alive, . .	143	=94.70 per cent., or about 95 per cent.
Total, ...	151 eggs.	

Cluster 3.

Unfertilized eggs,	1	= 2.14 per cent., or about 2 per cent.
Eggs with dead embryos,	4	
Eggs apparently alive,	229	=97.86 per cent., or about 98 per cent.
Total,	234 eggs.	

Cluster 4.

Unfertilized eggs,	1	= 3.17 per cent., or about 3 per cent.
Eggs with dead embryos,	3	
Eggs apparently alive,	122	=96.83 per cent., or about 97 per cent.
Total,	126 eggs.	

Cluster 5.

Unfertilized eggs,	6	=12.93 per cent., or about 13 per cent.
Eggs with dead embryos,	32	
Eggs apparently alive,	256	=87.07 per cent., or about 87 per cent.
Total,	294 eggs.	

Averaging these 5 clusters we get this result: —

Dead eggs,	15	= 7.77 per cent., or about 7.5 per cent.
Eggs apparently alive,	178	=92.23 per cent., or about 92.5 per cent.
Total,	193 eggs.	

We notice also that the egg clusters from this place, where the wilt developed naturally, are considerably less than the normal size, about 2½ clusters being equal to 1 normal cluster. This, and the fact that only 7.5 per cent. of the eggs would fail to hatch, while in the experiment 17 per cent. were dead, is probably due to the fact that upon this southern slope Flacherie appeared late and spread but slowly.

North Carver, Mass.

Division Agent, JOHN A. FARLEY; *Local Superintendent,* HERBERT F. ATWOOD.

This locality was visited on May 9, 1910, with the inspector of the southern districts of the State of Massachusetts, Mr. Norman Souther of Bridgewater, to find suitable places for the intended experiments. The gypsy moth does not occur here in such enormous numbers as in the northern parts of the State, but I wished to have some experiments at places where the gypsy moth has but recently gained a foothold.

An isolated wood of about 2 acres, situated somewhat southwest from Makepeace's cranberry bog, was found to be a suitable place. It consists of pines about forty years old and of oaks about twenty to twenty-five years of age, with considerable brush.

The gypsy moth was discovered here for the first time during the winter of 1909–10, by finding egg clusters. Several of these clusters, unfortunately, had been already killed with creosote before my first visit, but there were present, according to Mr. Souther's and my estimation, about 25 clusters. Whether there was any disease among the caterpillars of the previous year could not be ascertained, but it is highly improbable, considering the youth of the colony and the large size of the clusters.

On June 14, 1910, the local superintendent sent me word that wilt had made its appearance among the caterpillars which he had collected and fed according to instructions. I therefore went to North Carver on June 16, and found that in Mr. Atwood's colony about 3 per cent. of the caterpillars had already died of Flacherie. Most of those still living were very sick. He therefore had developed the wilt artificially after a feeding of about fourteen days.

This same day, with the assistance of the local superintendent, a part of the breeding material was exposed on the western side of the selected place. The bag containing the material was fastened about 8 feet from the ground, between young oak trees. Most of the caterpillars of this locality had just passed the third molt.

On Oct. 7, 1910, an extended search was made by the local superintendent and myself, but only 4 fresh clusters could be found. The microscopic examination of these 4 clusters resulted as follows: —

Cluster 1.

Unfertilized eggs, ...	5	= 6.03 per cent., or about 6 per cent.
Eggs with dead embryos,	21	
Eggs apparently alive, . .	405	=93.97 per cent., or about 94 per cent.
Total, ...	431 eggs.	

Cluster 2.

Unfertilized eggs, ...	3	= 5.38 per cent., or about 5.5 per cent.
Eggs with dead embryos, .	18	
Eggs apparently alive, . .	375	=94.62 per cent., or about 94.5 per cent.
Total, ...	396 eggs.	

Cluster 3.

Unfertilized eggs, ...	2	= 4.65 per cent., or about 4.5 per cent.
Eggs with dead embryos, .	8	
Eggs apparently alive, . .	205	=95.35 per cent., or about 95.5 per cent.
Total, ...	215 eggs.	

Cluster 4.

Unfertilized eggs, ...	3	=13.38 per cent., or about 13.5 per cent.
Eggs with dead embryos,	18	
Eggs apparently alive, . .	136	=86.62 per cent., or about 86.5 per cent
Total, . . .	157 eggs.	

Averaging these 4 clusters we get: —

Dead eggs, ...	20	= 6.67 per cent., or about 6.5 per cent.
Eggs apparently alive, . .	280	=93.33 per cent., or about 93.5 per cent.
Total, ...	300 eggs.	

Since, as we have seen, a normal cluster contains on the average 433 eggs with apparently living embryos, the living eggs of these 4 clusters, after the wilt did its work, amount to about 64.5 per cent. The egg clusters which were present in the spring of 1910 were estimated at about 25, while only 4 fresh clusters were found in the autumn of 1910. The total number of all apparently living eggs was decreased in this locality to about 13 per cent., as compared with the number present in the spring of 1910.

Another place for experiments, very similar to the last one, was selected in North Carver. This is a forest district of 3 acres, and is situated east of the cemetery on Wenham Street. The timber and brush here are the same as in the other locality, and the egg clusters of the gypsy moth were also first discovered here during the winter of 1909–10. Unfortunately, several clusters were killed with creosote before my first visit. The clusters still present were estimated by Mr. Souther and myself at about 600. On account of the young age of the colony and the considerable size of the clusters probably no disease had appeared among the caterpillars of the preceding year.

The remaining part of the wilt material was planted among the caterpillars of this locality on the same day and in the same manner as in the first colony. Here, also, most of the caterpillars at this time had just undergone the third molt.

The estimate of the fresh clusters, which was made by the local superintendent and myself Oct. 7, 1910, was about 400, from which the first 5 found were used for microscopical examinations. The result is as follows: —

Cluster 1.

Unfertilized eggs, ...	–	= 4.11 per cent., or about 4 per cent.
Eggs with dead embryos, .	12	
Eggs apparently alive, . .	280	=95.89 per cent., or about 96 per cent.
Total, . . .	292 eggs.	

Cluster 2.

Unfertilized eggs, ...	2	=17.17 per cent., or about 17 per cent.
Eggs with dead embryos, .	38	
Eggs apparently alive, . .	193	=82.83 per cent., or about 83 per cent.
Total, ...	233 eggs.	

Cluster 3.

Unfertilized eggs, ...	–	= 7.38 per cent., or about 7 per cent.
Eggs with dead embryos, .	9	
Eggs apparently alive, . .	113	=92.62 per cent., or about 93 per cent.
Total, . . .	122 eggs.	

Cluster 4.

Unfertilized eggs, ...	1	= 4.89 per cent., or about 5 per cent.
Eggs with dead embryos, .	14	
Eggs apparently alive, . .	292	=95.11 per cent., or about 95 per cent.
Total, ...	307 eggs.	

Cluster 5.

Unfertilized eggs, ...	2	= 2.95 per cent., or about 3 per cent.
Eggs with dead embryos, .	9	
Eggs apparently alive, . .	362	=97.05 per cent., or about 97 per cent.
Total, ...	373 eggs.	

Averaging these 5 clusters we get: —

Dead eggs, ...	17	= 6.42 per cent., or about 6.5 per cent.
Eggs apparently alive, . .	248	=93.58 per cent., or about 93.5 per cent.
Total, ...	265 eggs.	

Since this place, after infection with Flacherie, contains on the average only 248 eggs with apparently living embryos per cluster, almost 2 clusters of this locality are necessary to equal a normal cluster. The number of the fresh clusters, estimated at about 400, thus has to be reduced to about 250. The number of apparently living eggs in this locality therefore decreased, after the wilt had operated, to about 42 per cent.[1]

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[1] This forest was cut down by the owner in the beginning of the winter of 1910–11, and all egg clusters which the forest contained were collected by the local superintendent; 444 clusters were found. Our estimate of the clusters in the autumn, which was 400, therefore was nearly correct. The number of apparently living eggs which remained after Flacherie did its work has to be increased 3 per cent., that is to say, to 45 per cent.

Boxford, Mass.

Division Agent, FRANCIS C. WORTHEN; *Assistant Local Superintendent,* HARRY L. COLE.

Two places were selected in the West Boxford district for the intended experiments. The locality which we shall consider first is situated opposite the almshouse, near the Almshouse Road, and is only about a quarter of an acre in size. This small isolated wood is composed of oaks almost fifty to sixty years of age, and there is no brush. The gypsy moth caterpillars were numerous here in the summer of 1909. No disease had been noticed among them, according to Mr. Worthen and Mr. Cole, nor have any artificial means of destroying the gypsy moth been undertaken here. Mr. Worthen and I estimated the number of egg clusters at the time of my first visit, on May 6, 1910, at about 200.

Mr. Cole was intrusted with raising the caterpillars for the Boxford experiments. Having received no notice of the wilt making its appearance in the brood, on the 14th of June, 1910, I went to Boxford to inspect the material. It was found that Mr. Cole had reared the caterpillars in a very cold cellar, where they were eating but little and were retarded considerably in their development. He was instructed to place the caterpillars immediately in a warmer place in the open air. On June 19, 1910, a letter from him announced that Flacherie had broken out in his brood. On June 21 I went to Boxford to confirm his statement. About 5 per cent. of the caterpillars of this brood had already died of Flacherie, and most of the individuals still living showed all the signs of the disease.

One part of this brood was exposed, with the assistance of Mr. Cole, on the same day in the western part of the selected locality. The bag containing the material was fastened between twigs of oak trees, about 6 feet from the ground. Most of the caterpillars of this locality were at this time about ready for the fourth molt.

The fresh clusters at this place were estimated, on Aug. 26, 1910, by the division agent and myself, to be about 60. The first 5 clusters which were found were collected and examined. The examination resulted as follows: —

Cluster 1.

Unfertilized eggs,	–	= 4.92 per cent., or about 5 per cent.
Eggs with dead embryos,	6	
Eggs apparently alive,	116	=95.08 per cent., or about 95 per cent.
Total,	122 eggs.	

Cluster 2.

Unfertilized eggs,	1	=10.16 per cent., or about 10 per cent.
Eggs with dead embryos,	12	
Eggs apparently alive,	115	=89.84 per cent., or about 90 per cent.
Total,	128 eggs.	

Cluster 3.

Unfertilized eggs,	3	= 7.14 per cent., or about 7 per cent.
Eggs with dead embryos,	4	
Eggs apparently alive,	91	=92.86 per cent., or about 93 per cent.
Total,	98 eggs.	

Cluster 4.

Unfertilized eggs,	8	=28.24 per cent., or about 28 per cent.
Eggs with dead embryos,	16	
Eggs apparently alive,	61	=71.76 per cent., or about 72 per cent.
Total,	85 eggs.	

Cluster 5.

Unfertilized eggs,	–	= 2.96 per cent., or about 3 per cent.
Eggs with dead embryos,	5	
Eggs apparently alive,	164	=97.04 per cent., or about 97 per cent.
Total,	169 eggs.	

The average of these 5 clusters gives the following result: —

Dead eggs,	11	= 9.17 per cent., or about 9 per cent.
Eggs apparently alive,	109	=90.83 per cent., or about 91 per cent.
Total,	120 eggs.	

Since this place, weakened by the wilt, contained only 109 eggs with apparently living embryos to the cluster, almost 4 clusters were necessary to equal the size of a normal cluster. The number of fresh egg clusters, which were estimated at 60, thus must be reduced to about 20 clusters. The number of apparently living eggs was therefore decreased, as the result of Flacherie, to about 10 per cent.

The second place which was selected in West Boxford for experiments with the disease consists of an isolated wood of about half an acre. Most of the trees are oaks about thirty years of age, mixed with underbrush. This locality is situated on Highland Street, between two apple orchards. In the summer of 1909 the gypsy moth caterpillars were relatively more numerous than at the first place. No disease was noticed among them by Messrs. Worthen and Cole, but it is nevertheless possible that the wilt might have made its appearance. No artificial means for destroying the gypsy moth had been undertaken here. The number of egg clusters present at the time of my first visit in the spring of 1910 was estimated by Mr. Worthen and myself at about 550.

Flacherie, which had been developed artificially by Mr. Cole, was planted in this locality June 21, 1910, in the same manner as in the place first described. The caterpillars were about ready for the fourth molt, as in the first experiment. With the assistance of the division agent the fresh clusters at this locality were estimated on Aug. 26, 1910, to be about 80. The microscopical examination of the first 5 clusters found shows: —

Cluster 1.

Unfertilized eggs,	1	= 6.67 per cent., or about 6.5 per cent.
Eggs with dead embryos,	10	
Eggs apparently alive,	154	=93.33 per cent., or about 93.5 per cent.
Total,	165 eggs.	

Cluster 2.

Unfertilized eggs,	1	= 6.25 per cent., or about 6 per cent.
Eggs with dead embryos,	5	
Eggs apparently alive,	90	=93.75 per cent., or about 94 per cent.
Total,	96 eggs.	

Cluster 3.

Unfertilized eggs,	2	= 7.09 per cent., or about 7 per cent.
Eggs with dead embryos,	7	
Eggs apparently alive,	118	=92.91 per cent., or about 93 per cent.
Total,	127 eggs.	

Cluster 4.

Unfertilized eggs,	3	= 9.68 per cent., or about 9.5 per cent.
Eggs with dead embryos,	12	
Eggs apparently alive,	140	=90.32 per cent., or about 90.5 per cent.
Total,	155 eggs.	

Cluster 5.

This cluster proved to be entirely without eggs, and it consisted only of a mass of wool of about 1 square centimeter in size. The female moth, which deposited this cluster, seems to have been absolutely sterile. It started mechanically, it is true, to lay eggs, but of course it could deposit nothing except the hairs from its abdomen.

The average of these clusters gives the following result: —

Dead eggs,	8	= 7.34 per cent., or about 7 per cent.
Eggs apparently alive,	101	=92.66 per cent., or about 93 per cent.
Total,	109 eggs.	

Since this locality, which had been infected with the wilt, showed only 101 eggs with apparently living embryos on the average per cluster, about 4 clusters would be equal to a normal one. The fresh egg clusters, which were estimated at about 80, thus have to be reduced to about 20. The number of apparently living eggs in this infested locality has thus decreased to about 4 per cent.

A third locality in which the wilt appeared naturally was somewhat closely inspected. A small isolated wood of about 3,000 square feet is situated on Main Street, about 500 yards south of Wood's Corner. The trees consist of oaks a hundred years or more of age, and the place is free from underbrush. The gypsy moth caterpillars were very numerous here in the summer of 1909, but no definite statement can be made as to whether or not there was disease among them. If the disease was present, it was doing little harm, as otherwise dead caterpillars in large numbers would have been noticed, without doubt, by the division agent or the local superintendent. Mr. Worthen estimated the number of clusters present in the spring of 1910 at about 400. No artificial means for destroying the gypsy moth were undertaken. Measured in a straight line this place is at least 1 mile from the nearest of the two localities previously mentioned. Flacherie was noticed here at a time when most caterpillars were in the fourth molt. Here, too, the disease worked considerably among the caterpillars. It was hard to find even 50 clusters when Mr. Worthen and I estimated the freshly laid ones, on Aug. 26, 1910. For comparison the first 5 clusters found were collected and examined. They gave the following results: —

Cluster 1.

Unfertilized eggs,	–	=11.27 per cent., or about 11 per cent.
Eggs with dead embryos,	8	
Eggs apparently alive,	63	=88.73 per cent., or about 89 per cent.
Total,	71 eggs.	

Cluster 2.

Unfertilized eggs,	1	=10.28 per cent., or about 10 per cent.
Eggs with dead embryos,	10	
Eggs apparently alive,	96	=89.72 per cent., or about 90 per cent.
Total,	107 eggs.	

Cluster 3.

Unfertilized eggs, ...	2	= 6.94 per cent., or about 7 per cent.
Eggs with dead embryos, .	8	
Eggs apparently alive, .	134	=93.06 per cent., or about 93 per cent.
Total, ...	144 eggs.	

Cluster 4.

Unfertilized eggs, ...	–	= 4.26 per cent., or about 4 per cent.
Eggs with dead embryos, .	4	
Eggs apparently alive, .	90	=95.74 per cent., or about 96 per cent.
Total, . . .	94 eggs.	

Cluster 5.

Unfertilized eggs, . .	2	= 8.59 per cent., or about 8.5 per cent.
Eggs with dead embryos, .	12	
Eggs apparently alive, . .	149	=91.41 per cent., or about 91.5 per cent.
Total, . . .	163 eggs.	

The average of these 5 clusters gives the following result: —

Dead eggs, ...	9	= 7.08 per cent., or about 7 per cent.
Eggs apparently alive, .	106	=92.92 per cent., or about 93 per cent.
Total, . . .	115 eggs.	

Thus in this locality, also, in which the wilt appeared naturally, the egg clusters were far below the normal size. Examination showed that about 4 of these clusters would be necessary to equal a normal one in size. The estimated sum of 50 clusters, therefore, must be reduced to about 14. Hence, the apparently living eggs which remained amount to about 4 per cent.

Finally, a forest of about 30 acres was inspected. This is situated at an angle of 45°, and half a mile distant from the two first localities. In this forest, which consists mainly of large pines and oaks, the gypsy moth caterpillars had been present in considerable numbers during the summer of 1909, and were still more numerous during the first part of the summer of 1910. The owners of this place intended, according to the division agent, to cut down the forest, thus preventing a total stripping and decrease of the value of the wood. A powerful ally came to the support of the owners during the latter part of the summer of 1910, in the guise of Flacherie, which cleared up the caterpillars in a manner that left nothing to be desired. It cannot be determined whether the disease appeared naturally or was spread to this forest from the two localities in which the experiments were performed. However this may be, the wilt had acted at any rate in such a virulent manner that in all these 30 acres of forest not a single fresh egg cluster could be found, notwithstanding the most painstaking search on the part of Mr. Worthen and myself.

Mr. Worthen also undertook, on his own behalf, the breeding of several hundred caterpillars, feeding them according to my instructions. The disease could be noticed in this brood as early as June 14, 1910. Most of these caterpillars had just passed the third molt. Three days later he exposed all the material among the caterpillars of a forest near his home. Soon he observed the "dying off" of the caterpillars which were there present. The number of the dead ones grew astonishingly, but the final result cannot be stated, since, unfortunately, the trees were later sprayed with arsenate of lead.

West Bedford, Mass.

The division agent and the local superintendent in this locality were not requested to perform the experiments. My friend, Mr. L. W. Swett, the well-known specialist in Geometridæ, asked me in the spring of 1910 to undertake an experiment with the wilt upon his estate on Davis Street, northeast of the railroad station, in West Bedford. We inspected the place for this purpose on May 29, and the locality appeared to be a very suitable one for the work. It consists of two isolated strips of wood, which meet at a right angle. One strip comprises oaks about fifty years of age, mixed with some brush; while the other consists of dense birch brush about six years old. The whole locality comprises about three-quarters of an acre. The gypsy moth was first discovered here in 1908, and the place since that time has been under continuous observation by Mr. Swett. He assured me that there were positively no signs of a disease among the caterpillars. During the summer of 1909 the caterpillars were quite numerous. Part of the egg clusters, which were laid in the autumn of 1909, were killed with creosote, but there were still present, according to Mr. Swett's and my estimation at the time of my first visit, about 400 clusters on the oaks and about 100 clusters on the birches.

The caterpillars for this experiment were raised by the author at Forest Hills. They began to die from Flacherie after a continuous feeding of fourteen days, and just as they had passed the third molt. This material was planted, June 22, 1910, in the birch brush, and the bag was fastened about 6 feet from the ground. Most of the caterpillars of this locality were at that time half way between the third and fourth molt. The place was visited again on July 18, 1910, to determine the progress of the disease. Mr. Swett and I found that the caterpillars were dying in considerable numbers, and the percentage of dead individuals was greatest on the shortest brush, and decreased gradually the higher the vegetation grew. For instance, all the caterpillars which had been feeding on the small willow brushes were already dead. This brush, hardly 3 feet high, occurs here and there in front of the two rows of woods. The dead caterpillars were readily seen, as they were hanging all over the brush. Many of the caterpillars on the birches were dying, but a considerable number of living individuals was still present. In the colony of the high oaks, however, the wilt had not spread so much, although dead individuals were found in considerable numbers.

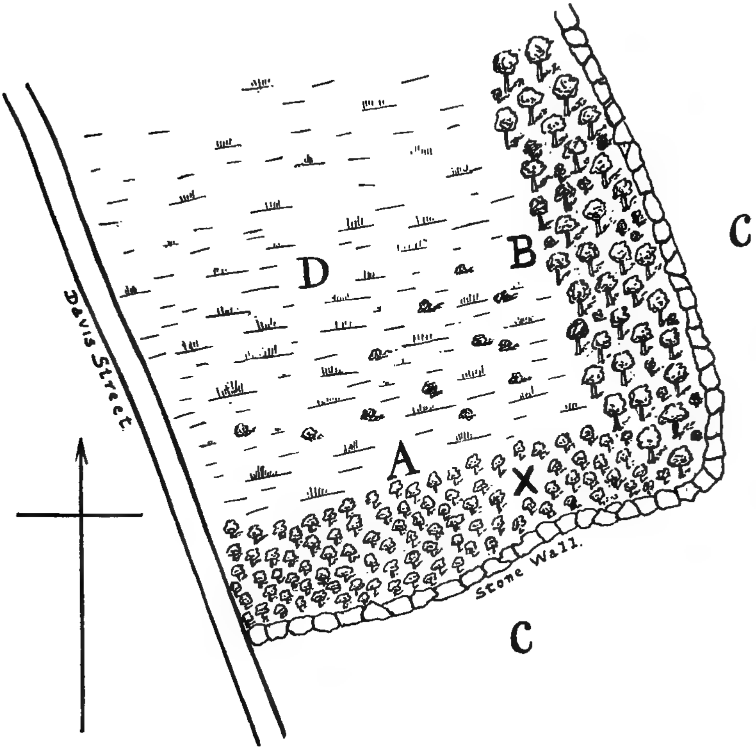

Fig. 3.—Experiment, West Bedford, Mass. A. Dense birches. X. Exposure of disease. B. Oaks and underwood. C. Field. D. Marshy meadow with a few scattered willows.

On Sept. 23, 1910, the freshly laid egg clusters were estimated. We made the interesting discovery that there existed no fresh clusters in the row overgrown with birch. Thus, all the caterpillars, at least the females, had been killed by Flacherie. To be certain of this fact the crevices of the bordering stone wall were carefully examined, since the gypsy moth female selects with preference such hidden places for oviposition. But no fresh clusters could be found here. The other row with the high oaks, however, proved to have a relatively large number of fresh clusters, which were estimated at about 150. Mr. Swett later made an examination and confirmed these facts. There is no sufficient explanation so far for the peculiar behavior of the wilt in this locality. Apparently the wind here played a special rôle. The difference in the vegetation may also have had some influence. Does the eating of birch foliage hasten the production of the disposition to Flacherie among the caterpillars?

The accompanying map will complete the description of the West Bedford locality (Fig. 3).

The microscopic examination of the 5 first egg clusters, found on the oaks, gave the following result: —

Cluster 1.

Unfertilized eggs, ...	–	= 2.69 per cent., or about 2.5 per cent.
Eggs with dead embryos, .	5	
Eggs apparently alive, .	181	=97.31 per cent., or about 97.5 per cent.
Total, ...	186 eggs.	

Cluster 2.

Unfertilized eggs, ...	2	= 2.67 per cent., or about 2.5 per cent.
Eggs with dead embryos, .	7	
Eggs apparently alive, .	328	=97.33 per cent., or about 97.5 per cent.
Total, . .	337 eggs.	

Cluster 3.

Unfertilized eggs, ...	1	= 3.25 per cent., or about 3 per cent.
Eggs with dead embryos,	4	
Eggs apparently alive, . .	149	=96.75 per cent., or about 97 per cent.
Total, ...	154 eggs.	

Cluster 4.

Unfertilized eggs, . .	12	=20.65 per cent., or about 20.5 per cent.
Eggs with dead embryos, .	58	
Eggs apparently alive, . .	269	=79.35 per cent., or about 79.5 per cent.
Total, ...	339 eggs.	

Cluster 5.

Unfertilized eggs, . .	1	= 3.19 per cent., or about 3 per cent.
Eggs with dead embryos, .	9	
Eggs apparently alive, . .	303	=96.81 per cent., or about 97 per cent.
Total, ...	313 eggs.	

The average of these 5 clusters gives the following result: —

Dead eggs, ...	20	= 7.52 per cent., or about 7.5 per cent.
Eggs apparently alive, .	246	=92.48 per cent., or about 92.5 per cent.
Total,	266 eggs.	

Since this locality, in which the wilt has worked, contained only 246 eggs with apparently living embryos in average per cluster, nearly 2 clusters were necessary to equal a single normal cluster. The number of fresh clusters, which were estimated at about 150, must therefore be reduced to about 90. The number of apparently living eggs of that part of this locality which bears the oaks was therefore decreased to about 22.5 per cent. after the wilt had worked, while, as already mentioned, the part with the birches contained probably no living eggs.

Haverhill, Mass.

Division Agent, H. F. ARMSTRONG; *Local Superintendent,* G. F. MOORE.

With the assistance of the local superintendent a place was selected for the experiment in East Parish, Haverhill; it is situated west of East Broadway and northeast of Millway Pond, and on the Old Country Road. This locality represents almost 50 acres of isolated forest, in which oaks about thirty years old, mixed with underbrush, prevail. Only about 12 acres of this forest are infested with the gypsy moth. The caterpillars were numerous here during the summer of 1909, but no disease was present, according to the local superintendent. On May 18, 1910, our joint estimation gave 1,000 clusters per acre, *i.e.,* altogether about 12,000 clusters. No artificial means of destroying the gypsy moth had been undertaken.

Mr. Moore, owing to lack of time, could not raise caterpillars for the experiment, and he had no reliable man to whom he could entrust the work. Upon the recommendation of Mr. Fitzgerald, the field inspector of the northern divisions,' the brother of the local superintendent of Methuen, Mass., Mr. Wagland, was intrusted with the raising of the caterpillars. As no communication was received from Mr. Walter Wagland by June 21, 1910, that his caterpillars showed signs of Flacherie, I went on this day to Methuen, to convince myself of the condition of the insects. The local superintendent, A. H. Wagland, Mr. Walter Wagland's brother, was with me, and we found that all the caterpillars were sick and that several had already died. The reason why I had received no word from Mr. Walter Wagland was that he did not recognize the disease. The planting of the material in the selected place in Haverhill was accomplished the next day. All the material was exposed in a pasteboard box in the western part of the forest, about 6 feet from the ground and between limbs of oak trees.

Most of the caterpillars of this locality were at this time about half way between the third and fourth molts.

The place was visited again Aug. 30, 1910, with the local superintendent of Haverhill, to see how the wilt had operated, and how many fresh egg clusters were present. First it was noticed that the infested portion of the forest was not uniformly infected with Flacherie. While the periphery of the infested area (about 8 to 9 acres) showed a very considerable decrease of the egg clusters in comparison with those of the spring of 1910, the real center of the colony, which covered 3 to 4 acres, had been more resistant to the disease, although here also the number of the fresh clusters had decreased considerably in comparison with the clusters of the previous year. Altogether the number of fresh clusters of the whole colony was estimated by us to be about 3,500. The 5 clusters which served for examination proved to be as follows: —

Cluster 1.

Unfertilized eggs,	8	=28.57 per cent., or about 28.5 per cent.
Eggs with dead embryos,	28	
Eggs apparently alive,	90	=71.43 per cent., or about 71.5 per cent.
Total,	126 eggs.	

Cluster 2.

Unfertilized eggs,	–	= 3.31 per cent., or about 3 per cent.
Eggs with dead embryos,	5	
Eggs apparently alive,	146	=96.69 per cent., or about 97 per cent.
Total,	151 eggs.	

Cluster 3.

Unfertilized eggs,	4	= 5.63 per cent., or about 5.5 per cent.
Eggs with dead embryos,	13	
Eggs apparently alive,	285	=94.37 per cent., or about 94.5 per cent.
Total,	302 eggs.	

Cluster 4.

Unfertilized eggs,	7	=12.36 per cent., or about 12 per cent.
Eggs with dead embryos,	25	
Eggs apparently alive,	227	=87.64 per cent., or about 88 per cent.
Total,	259 eggs.	

Cluster 5.

Unfertilized eggs,	–	= 1.95 per cent., or about 2 per cent.
Eggs with dead embryos,	6	
Eggs apparently alive,	302	=98.05 per cent., or about 98 per cent.
Total,	308 eggs.	

The average of these 5 clusters gives the following result: —

Dead eggs, ...	19	= 8.30 per cent., or about 8 per cent.
Eggs apparently alive,	210	=91.70 per cent., or about 92 per cent.
Total, . . .	229 eggs.	

Since a normal cluster contains, on the average, 433 eggs with apparently living embryos, and this locality in which Flacherie had prevailed contained only 210 eggs with apparently living embryos on the average per cluster, 2 clusters were necessary to equal a normal one. The number of fresh clusters, which were estimated to be about 3,500, must therefore be reduced to about 1,750. The number of apparently living eggs had decreased in this locality, after the wilt had operated, to about 14.5 per cent.

Marshfield, Mass.

Division Agent, John A. Farley; *Local Superintendent,* P. R. Livermore.

I did not visit this locality, but the experiment was undertaken by the local superintendent with the assistance of Mr. Joseph Shermann of Marshfield, who raised the caterpillars according to my instructions. On visiting Marshfield on June 24, 1910, it was found that Mr. Shermann's caterpillars, most of which were ready to undergo the fourth molt, were sick with Flacherie. He was instructed to expose the material, with the assistance of the local superintendent, in a forest infested with the gypsy moth. This was done on June 26, 1910, in a forest of 10 acres. On Oct. 25, 1910, the local superintendent sent, upon my request, a number of fresh egg clusters from the locality where the disease had been planted, and he remarked that the number of egg clusters were considerably decreased in comparison with those present in the spring of 1910. Unfortunately, further detailed communications regarding this locality were not received. The first 5 clusters, which were taken from the top of the shipment, were examined microscopically. The result was as follows: —

Cluster 1.

Unfertilized eggs, . . .	1	= 4.26 per cent., or about 4 per cent.
Eggs with dead embryos, .	10	
Eggs apparently alive, . .	247	=95.74 per cent., or about 96 per cent.
Total, ...	258 eggs.	

Cluster 2.

Unfertilized eggs, . . .	8	=13.47 per cent., or about 13.5 per cent.
Eggs with dead embryos, .	65	
Eggs apparently alive, .	469	=86.53 per cent., or about 86.5 per cent.
Total, ...	542 eggs.	

Cluster 3.

Unfertilized eggs, . .	2	=10.59 per cent., or about 10.5 per cent.
Eggs with dead embryos, .	41	
Eggs apparently alive, . .	363	=89.41 per cent., or about 89.5 per cent.
Total, . .	406 eggs.	

Cluster 4.

Unfertilized eggs, . . .	1	= 5.28 per cent., or about 5 per cent.
Eggs with dead embryos,	14	
Eggs apparently alive, .	269	=94.72 per cent., or about 95 per cent.
Total, . . .	284 eggs.	

Cluster 5.

Unfertilized eggs, . .	4	= 6.64 per cent., or about 6.5 per cent.
Eggs with dead embryos,	9	
Eggs apparently alive, .	181	=93.36 per cent., or about 93.5 per cent.
Total, . . .	194 eggs.	

The average of these 5 clusters gives the following result: —

Dead eggs, ...	31	= 9.20 per cent., or about 9 per cent.
Eggs apparently alive, . .	306	=90.80 per cent., or about 91 per cent.
Total, . . .	337 eggs.	

After the wilt had operated in this locality the size of the egg clusters was not up to the average size of the normal cluster, and the percentage of dead eggs was very high.

Kingston, Mass.

Division Agent, JOHN A. FARLEY; *Local Superintendent,* C. C. FAUNCE.

With the help of the field inspector, Mr. Norman Souther of Bridgewater, two places were selected for the intended experiments. The locality which we will first consider is an isolated part of the so-called "Rocky Nook," and is situated about 1 mile east of the Kingston-Plymouth car line. This place is about a quarter of an acre in size and mainly overgrown with oaks about twenty-five years of age. The gypsy moths were discovered here in the autumn of 1909 by finding egg clusters. The youth of the colony made it seem improbable that there was any disease among the caterpillars of 1909, and, moreover, the egg clusters had a considerable size. Several of the clusters found had been killed with creosote, but there were still left about 60 clusters, according to Mr. Souther's and my estimate.

The local superintendent was intrusted by Mr. Souther with the breeding of caterpillars. On June 24, 1910, I found the wilt in this brood. The same day, with the assistance of the local superintendent, one part of the material was exposed in the locality mentioned. This brood was thoroughly sick, but the "dying off" of the caterpillars had not begun. The bag containing the material was fastened between twigs about 7 feet from the ground. The caterpillars in this locality were at this time half way between the third and fourth molt.[1]

On Oct. 25, 1910, the fresh egg clusters of this locality were estimated by the local superintendent and myself. We found that the place contained almost the same numbers of clusters as in the spring of 1910, with the difference, however, that many clusters had the hairy covering only in part. Several clusters completely lacked this covering. It seems that the disease spread very slowly, and that it did not kill many caterpillars but had merely given them a mild form of the disease, which manifested itself later in the manner mentioned, when the females laid their eggs. The 5 clusters which were first found were examined, like those of other localities. The examination gave the following interesting results: —

Cluster 1.

Unfertilized eggs,	2	= 3.97 per cent., or about 4 per cent.
Eggs with dead embryos,	13	
Eggs apparently alive,	363	=96.03 per cent., or about 96 per cent.
Total,	378 eggs.	

Cluster 2.

Unfertilized eggs,	6	=18.85 per cent., or about 19 per cent.
Eggs with dead embryos,	92	
Eggs apparently alive,	422	=81.15 per cent., or about 81 per cent.
Total,	520 eggs.	

Cluster 3.

Unfertilized eggs,	2	=13.48 per cent., or about 13.5 per cent.
Eggs with dead embryos,	58	
Eggs apparently alive,	385	=86.52 per cent., or about 86.5 per cent.
Total,	445 eggs.	

Cluster 4.

Unfertilized eggs,	1	=20.98 per cent., or about 21 per cent.
Eggs with dead embryos,	123	
Eggs apparently alive,	467	=79.02 per cent., or about 79 per cent.
Total,	591 eggs.	

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[1] This experiment was intentionally undertaken with sick caterpillars only, and no dead ones, in order to see what effect the exposure of only sick individuals might have upon the healthy caterpillars in the field.

Cluster 5.

Unfertilized eggs, . .	–	= 6.06 per cent., or about 6 per cent.
Eggs with dead embryos,	2	
Eggs apparently alive, .	31	=93.94 per cent., or about 94 per cent.
Total, . .	33 eggs.	

The average of these 5 clusters gives the following result: —

Dead eggs, ...	60	= 15.23 per cent., or about 15 per cent.
Eggs apparently alive,	334	= 84.77 per cent., or about 85 per cent.
Total, . . .	394 eggs.	

Since this place, in which Flacherie had operated, contained on the average only 334 eggs with apparently living embryos per cluster, the size of these clusters was about one-quarter less than normal. The fresh clusters, which were estimated to be about 60, *i.e.,* the same number which was found in the spring, thus must be reduced to about 45. The number of apparently living eggs of this locality therefore was decreased, after the wilt had worked, to about 77 per cent.

This experiment also shows that the exposure of sick instead of dead caterpillars contributes to the spread of the wilt. As in such cases, however, the disease spreads slowly, the caterpillars, it is true, will not be killed in large numbers, but they will be infected more or less lightly. The result is that a high percentage of the eggs deposited by the females will fail to hatch.

The second place which was selected in Kingston for an experiment is situated on the eastern side of Jones River, opposite the poor farm. This is an isolated wood of about one-eighth of an acre in size, which contains several large oaks and underbrush. The gypsy moth was discovered here also by the finding of egg clusters first in the autumn of 1909. It cannot be stated whether disease was present among the caterpillars of the summer of 1909, but this seems improbable, owing to the youth of the colony. Several of the clusters were killed with creosote, but there were still left, according to Mr. Souther's estimate, about 50 clusters.

The planting of the sick material was accomplished on the same day and in the same manner as in the first locality. Estimating the fresh clusters on Oct. 25, 1910, unfortunately I found that most of these fresh clusters (about 25) had been already killed with creosote by the men working under the local superintendent. Even with the assistance of the local superintendent, only 2 untouched egg clusters could be found. Only 1 of these could be collected, since the second was out of reach. Although, therefore, we are unable to draw any complete and final conclusions in regard to the work of the wilt in this locality, nevertheless the result of the examination of the single cluster which could be secured may be given: —

Unfertilized eggs, . .	1	= 3.52 per cent., or about 3.5 per cent.
Eggs with dead embryos,	12	
Eggs apparently alive, . .	356	=96.48 per cent., or about 96.5 per cent.
Total, ...	369 eggs.	

All we can say concerning this locality is that through the operation of Flacherie, which was introduced by sick material only, the number of fresh clusters seems to have been reduced in comparison with that of the previous year.

Brockton, Mass.

Division Agent, L. W. Hodgkins; *Local Superintendent,* E. Moltan.

The place which, with the assistance of the inspector, Mr. Norman Souther of Bridgewater, was selected for an experiment, is situated near Oak Street, northwest of Brockton Center and east of the Dutchland Farm. The place, of about half an acre, consists of a growth of oaks about forty to fifty years of age; no brush is present. The caterpillars of the gypsy moth were abundant here in the summer of 1909, but no disease was noticed among them. Several of the clusters were killed with creosote during the winter of 1909–10. The clusters which were left were estimated by Mr. Souther and myself to be about 40.

The raising of caterpillars for the intended experiment Mr. Souther intrusted to Mr. Rudolph Marshall, 218 Battle Street, Brockton. On June 24, 1910, the brood was inspected. Several caterpillars had already died from the wilt and the others were found to be sick. This same day the whole material was exposed in the selected place. The bag was fastened between oak limbs, about 8 feet from the ground. Most of the caterpillars of this locality were at this time about half way between the third and fourth molt.

This place was visited again on Oct. 7, 1910, with Mr. Souther, to determine the number of fresh clusters. But in spite of the most strenuous search there were found but 4 clusters; these were collected for examination. They resulted as follows: —

Cluster 1.

Unfertilized eggs, . .	2	= 2.99 per cent., or about 3 per cent.
Eggs with dead embryos, .	10	
Eggs apparently alive, .	389	=97.01 per cent., or about 97 per cent.
Total, .	401 eggs.	

Cluster 2.

Unfertilized eggs,	13	=11.71 per cent., or about 11.5 per cent.
Eggs with dead embryos,	22	
Eggs apparently alive,	264	=88.29 per cent., or about 88.5 per cent.
Total,	299 eggs.	

Cluster 3.

Unfertilized eggs,	3	= 5.47 per cent., or about 5.5 per cent.
Eggs with dead embryos,	14	
Eggs apparently alive,	294	=94.53 per cent., or about 94.5 per cent.
Total,	311 eggs.	

Cluster 4.

Unfertilized eggs,	2	= 4.81 per cent., or about 5 per cent.
Eggs with dead embryos,	18	
Eggs apparently alive,	396	=95.19 per cent., or about 95 per cent.
Total,	416 eggs.	

The average of these 4 clusters gives the following result: —

Dead eggs,	21	= 5.88 per cent., or about 6 per cent.
Eggs apparently alive,	336	=94.12 per cent., or about 94 per cent.
Total,	357 eggs.	

Since this place, in which the wilt had operated, contained only 336 eggs with apparently living embryos on the average per cluster, the size of these clusters was about one-fourth less than normal. The number of the fresh clusters, which were found to be 4, must thus be reduced to 3. The number of apparently living eggs of this locality therefore was decreased, after Flacherie had worked, to about 7.5 per cent.

Beverly, Mass.

Division Agent, Saul Phillips; *Assistant,* W. F. Holmes.

With the help of the assistant of the division agent two places were selected for the experiments. The place which we will first consider is situated near Hart Street, north of Greenwood Avenue, Beverly Farms. It is an isolated wood of about 1 acre, mainly overgrown with maple about fifty to sixty years of age, and yellow birch, and has dense underbrush. The gypsy moth caterpillars were very numerous here during the summer of 1909, but no disease was noticed among them. A small percentage of egg clusters was killed with creosote during the winter of 1909–10. A joint estimate of the egg clusters in this locality made with the assistant of the division agent in the spring of 1910 resulted in finding about 500 clusters.

The rearing of caterpillars was undertaken by Mr. Phillips's assistant. On June 20, 1910, he noticed the first dead individuals in the brood. Three days after the receipt of this communication I went to Beverly to inspect the material. Many of the caterpillars had already died from the wilt. This same day (June 25), with the help of the assistant, one part of the material was exposed in the western portion of the locality mentioned. The bag containing the material was fastened about 6 feet from the ground, between limbs with dense foliage. Most of the caterpillars of this locality had at this time just passed the third molt.

After the wilt had operated all through the summer among the caterpillars of this locality, the place was visited again on Sept. 13, 1910, together with Mr. Phillips's assistant. We estimated the number of fresh clusters present to be about 250. The decrease in the size of the clusters compared with those of the previous year was very striking. The examination of the first 5 clusters which were found gave the following result: —

Cluster 1.

Unfertilized eggs,	5	=13.60 per cent., or about 13.5 per cent.
Eggs with dead embryos,	12	
Eggs apparently alive,	108	=86.40 per cent., or about 86.5 per cent.
Total,	125 eggs.	

Cluster 2.

Unfertilized eggs,	2	= 5.92 per cent., or about 6 per cent.
Eggs with dead embryos,	8	
Eggs apparently alive,	159	=94.08 per cent., or about 94 per cent.
Total,	169 eggs.	

Cluster 3.

Unfertilized eggs,	1	= 7.37 per cent., or about 7 per cent.
Eggs with dead embryos,	6	
Eggs apparently alive,	88	=92.63 per cent., or about 93 per cent.
Total,	95 eggs.	

Cluster 4.

Unfertilized eggs,	1	= 5.76 per cent., or about 5.5 per cent.
Eggs with dead embryos,	7	
Eggs apparently alive,	131	=94.24 per cent., or about 94.5 per cent.
Total,	139 eggs.	

Cluster 5.

Unfertilized eggs,	–	= 6.45 per cent., or about 6.5 per cent.
Eggs with dead embryos,	4	
Eggs apparently alive,	58	=93.55 per cent., or about 93.5 per cent.
Total,	62 eggs.	

The average of these 5 clusters gives the following result: —

Dead eggs,	9	= 7.63 per cent., or about 7.5 per cent.
Eggs apparently alive,	109	=92.37 per cent., or about 92.5 per cent.
Total,	118 eggs.	

Since a normal cluster contains on the average 433 eggs with apparently living embryos, and this place, in which Flacherie had operated, contained only 109 eggs with apparently living embryos on the average per cluster, about 4 clusters were necessary to equal the size of a normal one. The number of fresh clusters, which were estimated to be about 250, thus must be reduced to about 65. The number of apparently living eggs of this locality therefore was decreased, after the wilt had worked, to about 15 per cent.

For the second experiment a small isolated group of oaks, about eighty years of age, was selected. This place is situated near the railroad station, Beverly Farms, between the railroad track and the ocean. The caterpillars of the gypsy moth have always appeared here only in small numbers, and there were hardly more than one dozen clusters in the spring of 1910, according to our estimate. It must be mentioned, especially, that this locality is always exposed to very strong winds.

Flacherie, artificially developed by the assistant of the division agent, was planted among the caterpillars at this place on June 25, 1910, in the same manner as in the first locality. Considering the heavy breeze the material was placed in a wooden box, which was then fastened between limbs; thus the wind was not able to carry off the whole material. Most of the caterpillars of this place were about ready at this time to undergo the third molt.

On Sept. 13, 1910, this locality was visited again. The wilt had done very considerable damage to the caterpillars. Although the place was carefully searched with Mr. Holmes's assistance, we could find but 2 fresh clusters. One of these is especially remarkable, as it lacks completely the protecting covering. The microscopic examination of both clusters gave the following results: —

Cluster 1.

Unfertilized eggs, .	3	= 9.17 per cent., or about 9 per cent.
Eggs with dead embryos, .	8	
Eggs apparently alive, .	109	=90.83 per cent., or about 91 per cent.
Total, .	120 eggs.	

Cluster 2.[1]

Unfertilized eggs, . .	38	=87.50 per cent., or about 87.5 per cent.
Eggs with dead embryos,	116	
Eggs apparently alive, .	22	=12.50 per cent., or about 12.5 per cent.
Total, .	176 eggs.	

The average of these 2 clusters gives the following: —

Dead eggs,	83	=55.70 per cent., or about 55.5 per cent.
Eggs apparently alive, .	66	=44.30 per cent., or about 44.5 per cent.
Total, .	149 eggs.	

Since this place, in which Flacherie had operated, contained only 66 eggs with apparently living embryos on the average per cluster, the size of these clusters was about five-sixths less than normal. The number of fresh clusters, which were found to be 2, thus equal together only one-third of a normal one. The number of apparently living eggs of this locality therefore had decreased, after the wilt had worked, to about 3 per cent.

Cohasset, Mass.

Division Agent, F. A. Bates; *Local Superintendent,* J. E. Grassie.

An island, known as Barron's Island, which is situated southeast of Cohasset in the headpart of Bailey's Creek, was selected for the experiment. This island has an area of about 10 acres, and is densely overgrown, mostly with oaks about twenty-five years of age and with underbrush. The gypsy moth was quite numerous here in 1909, but there was no disease among the caterpillars, according to Mr. Grassie's statement. Our joint estimate of the clusters which were present in the spring of 1910 was about 2,000. No artificial means of destroying the gypsy moth had been undertaken here.

Mr. Grassie, who was intrusted with the breeding of the caterpillars, noticed the wilt in this brood after a feeding of about sixteen days. On June 27, 1910, the caterpillars were inspected, and there were found about 70 per cent. individuals already dead from the disease.[1] The same day all the material was exposed, with the assistance of Mr. Grassie, in the western part of the selected place, and about 6 feet from the ground. Most of the caterpillars of this locality were at this time about ready to undergo the fourth molt.

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[1] Without the protecting cover.

On Sept. 26, 1910, the island was visited again, in company of the local superintendent, to determine in what manner the wilt had operated among the caterpillars. An especially considerable reduction of the number of the fresh egg clusters, compared with those of the previous year, had not occurred. According to our estimate there were about 1,500 fresh clusters. The size of each of these clusters, compared with the clusters found in the spring of 1910, was diminished in such a degree, however, that the clusters were often no larger than a bean. The eggs also were often only covered in part with hair. This, as well as the comparatively small mortality and the smallness of the fresh clusters, may be perhaps a consequence of the late planting of the disease. It is true that a number of caterpillars were killed, but most of them only grew slightly sick, the disease again expressing itself at the time of oviposition. The fresh clusters of this locality were also of an abnormally light yellowish color, which was noticed nowhere else.

The examination of the first 5 clusters found gave the following result: —

Cluster 1.

Unfertilized eggs, ...	4	= 6.36 per cent., or about 6 per cent.
Eggs with dead embryos, .	7	
Eggs apparently alive, . .	162	=93.64 per cent., or about 94 per cent.
Total, . . .	173 eggs.	

Cluster 2.

Unfertilized eggs, . .	3	=23.68 per cent., or about 23.5 per cent.
Eggs with dead embryos, .	15	
Eggs apparently alive, .	58	=76.32 per cent., or about 76.5 per cent.
Total, ...	76 eggs.	

Cluster 3.

Unfertilized eggs, . .	1	=12.28 per cent., or about 12 per cent.
Eggs with dead embryos, .	6	
Eggs apparently alive, . .	50	=87.72 per cent., or about 88 per cent.
Total, . . .	57 eggs.	

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[1] It should be mentioned that Mr. Grassie sent a telephone communication on June 12, 1910, that the wilt had made its appearance among his caterpillars, but by a mistake I did not receive this notice until June 23.

Cluster 4.

Unfertilized eggs, . . .	5	=18.31 per cent., or about 18 per cent.
Eggs with dead embryos,	21	
Eggs apparently alive, . .	116	=81.69 per cent., or about 82 per cent.
Total, . . .	142 eggs.	

Cluster 5.

Unfertilized eggs, . .	8	=39.15 per cent., or about 39 per cent.
Eggs with dead embryos,	66	
Eggs apparently alive, . .	115	=60.85 per cent., or about 61 per cent.
Total, . . .	189 eggs.	

The average of these 5 clusters gives the following result: —

Dead eggs, ...	27	=21.26 per cent., or about 21 per cent.
Eggs apparently alive, .	100	=78.74 per cent., or about 79 per cent.
Total, . . .	127 eggs.	

Since this place, in which Flacherie had worked, contained only 100 eggs with apparently living embryos on the average per cluster, more than 4 clusters were necessary to equal a normal cluster. Thus the number of fresh clusters must be reduced to about 370. The number of apparently living eggs of this locality therefore had decreased, after the wilt had operated, to about 18 per cent.

Hingham, Mass.

Division Agent, F. A. Bates; *Local Superintendent,* A. W. Young.

For the experiment an island of about 1 acre was selected, very densely overgrown with low wood. This island is situated east of Water Street and south of the railroad track in the so-called Millpond. The wood consists mainly of oaks and birches of five to six years of age, and of underbrush. The gypsy moth was quite numerous here in the summer of 1909, but there was no disease among the caterpillars, according to the statements of the division agent and the local superintendent. Several of the clusters were killed with creosote during the winter of 1909–10. The number of the clusters which still remained was estimated by Mr. Young and myself to be about 100.

The breeding of a series of caterpillars was accomplished exactly according to my instructions by the local superintendent, but unfortunately he omitted to send word when the wilt made its appearance, since he had understood that he was to notify me only after all the caterpillars of the brood had died. To convince myself about the condition of the brood, I inspected the caterpillars July 1, 1910, and found that about 60 per cent. of them had succumbed to Flacherie. The first dead caterpillars were noticed by Mr. Young about fifteen days before. On the same day the whole of the material was exposed, with Mr. Young's assistance, in the southwestern part of the island, about 5 feet from the ground. Most of the caterpillars of this locality had at this time just undergone the fourth molt.

On Sept. 26, 1910, this island was visited, again in company with the local superintendent. We could see that the wilt had done very considerable damage to the caterpillars, for there were only a few scattered clusters. According to our estimate there were hardly 15 fresh clusters present; these, moreover, were much smaller in size than those of the previous year. It was also noticed that the clusters were often only partly covered with hair. All these conditions may well be attributed to Flacherie. The almost full-grown caterpillars had contracted the disease, and the females which then emerged from pupæ produced by these caterpillars were unable to oviposit like healthy moths.

The examination of the first 5 clusters found gave the following result: —

Cluster 1.

Unfertilized eggs,	3	= 9.56 per cent., or about 9.5 per cent.
Eggs with dead embryos,	10	
Eggs apparently alive,	123	=90.44 per cent., or about 90.5 per cent.
Total,	136 eggs.	

Cluster 2.

Unfertilized eggs,	3	= 8.82 per cent., or about 9 per cent.
Eggs with dead embryos,	12	
Eggs apparently alive,	155	=91.18 per cent., or about 91 per cent.
Total,	170 eggs.	

Cluster 3.

Unfertilized eggs,	1	= 4.73 per cent., or about 4.5 per cent.
Eggs with dead embryos,	7	
Eggs apparently alive,	161	=95.27 per cent., or about 95.5 per cent.
Total,	169 eggs.	

Cluster 4.

Unfertilized eggs,	2	=10.77 per cent., or about 10.5 per cent.
Eggs with dead embryos,	5	
Eggs apparently alive,	58	=89.23 per cent., or about 89.5 per cent.
Total,	65 eggs.	

Cluster 5.

Unfertilized eggs, ...	4	= 9.22 per cent., or about 9 per cent.
Eggs with dead embryos, .	9	
Eggs apparently alive, . .	128	=90.78 per cent., or about 91 per cent.
Total, . . .	141 eggs.	

The average of these 5 clusters gives the following result: —

Dead eggs, ...	11	= 8.09 per cent., or about 8 per cent.
Eggs apparently alive, . .	125	=91.91 per cent., or about 92 per cent.
Total, ...	136 eggs.	

Since this place, in which Flacherie had operated, contained only 125 eggs with apparently living embryos on the average per cluster, almost 4 clusters were necessary to equal a normal one. The number of the fresh clusters thus must be reduced to about 5. The number of apparently living eggs of this locality therefore had decreased, after the wilt had worked, to about 5 per cent.

Byfield, Mass.

On June 30, 1910, a letter was received from Mr. James O. Hale of Byfield, in which he stated that he had heard of my Flacherie experiments of 1909, and asked for aid in diminishing the gypsy moth caterpillars by using Flacherie. I therefore visited the locality on July 5, 1910, and took with me sick and dead caterpillars which had been raised at Forest Hills. The forest in question is about 4 to 5 acres in size, and consists mainly of oaks of different ages and some underbrush. It is situated on the border between Rowley and Newbury. It is not isolated, but connected with woods which belong to other persons. At the time of my arrival most of the caterpillars had already undergone the fifth molt, so that it seemed questionable whether the disease would be able to show much success this year. The infected material was exposed in the southwestern part of the forest, about 7 feet from the ground. It proved to be impossible to secure a correct estimate of the caterpillars which were present; all that could be stated was that the caterpillars were quite plentiful.

This locality was visited again with Mr. Hale on Sept. 16, 1910, to determine the results. Mr. Hale gave his opinion that there was, at the least, no increase in the number of egg clusters compared with that of the previous year, although there was no visible decrease in the number of the fresh clusters. However, these fresh clusters were considerably smaller than those of the preceding year.

The first 5 clusters collected gave the following counts: —

Cluster 1.

Unfertilized eggs,	2	= 8.33 per cent., or about 8 per cent.
Eggs with dead embryos,	6	
Eggs apparently alive,	88.	=91.67 per cent., or about 92 per cent.
Total,	96 eggs.	

Cluster 2.

Unfertilized eggs,	1	= 3.76 per cent., or about 3.5 per cent.
Eggs with dead embryos,	4	
Eggs apparently alive,	128	=96.24 per cent., or about 96.5 per cent.
Total,	133 eggs.	

Cluster 3.

Unfertilized eggs,	1	= 2.75 per cent., or about 2.5 per cent.
Eggs with dead embryos,	5	
Eggs apparently alive,	212	=97.25 per cent., or about 97.5 per cent.
Total,	218 eggs.	

Cluster 4.

Unfertilized eggs,	2	= 4.72 per cent., or about 4.5 per cent.
Eggs with dead embryos,	4	
Eggs apparently alive,	121	=95.28 per cent., or about 95.5 per cent.
Total,	127 eggs.	

Cluster 5.

Unfertilized eggs,	3	= 5.59 per cent., or about 5.5 per cent.
Eggs with dead embryos,	6	
Eggs apparently alive,	152	=94.41 per cent., or about 94.5 per cent.
Total,	161 eggs.	

The average of these 5 clusters gives the following result: —

Dead eggs,	7	= 4.76 per cent., or about 4.5 per cent.
Eggs apparently alive,	140	=95.24 per cent., or about 95.5 per cent.
Total,	147 eggs.	

We notice that the clusters of this locality in which the wilt had operated are far smaller than normal ones, since about 3 clusters are necessary to equal the size of a normal one. The percentage of dead eggs, however, does not attain that of other localities.

IV. Summary.

The artificially developed Flacherie was planted, after the "dying off" of the breeding material had begun, among the caterpillars of the gypsy moth in the following localities, the details in regard to these experiments being given in the preceding pages. The number of apparently living eggs was reduced to the following percentages: —

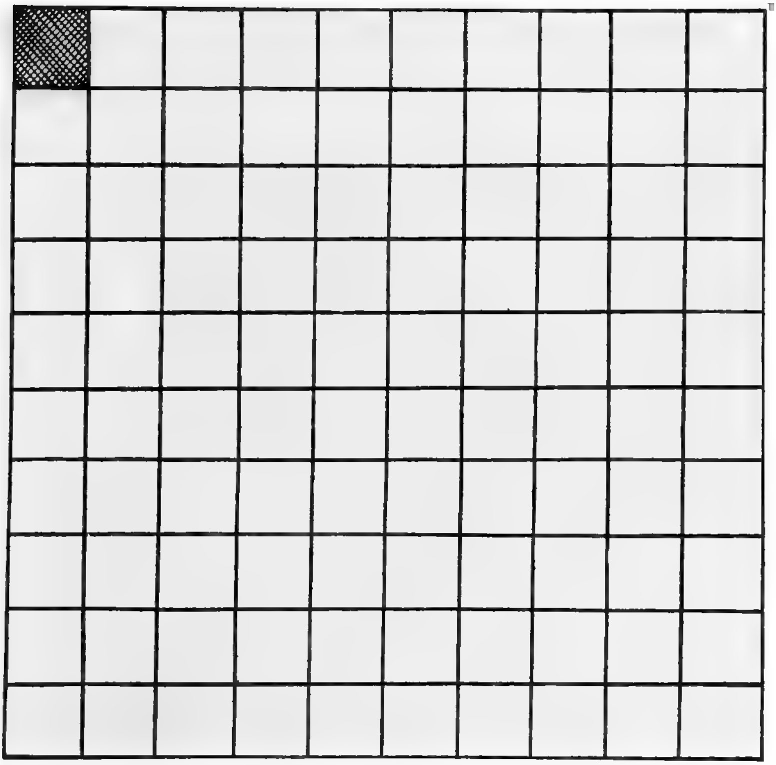

Fig. 4. — Diagram showing percentage of living eggs in healthy colonies.

	Per Cent.
Concord, Mass. (Brewster's estate),	11
Carver, Mass. (southwest of Makepeace's cranberry bog),	13
Carver, Mass. (on Wenham Street),	45
Boxford, Mass. (near the almshouse),	10
Boxford, Mass. (on Highland Street),	4
West Bedford, Mass. (Swett's estate), 0 per cent. + 22½ per cent. =	11½
Haverhill, Mass. (west of East Broadway),	14½

	Per Cent.
Brockton, Mass. (on Oak Street),	7½
Beverly, Mass. (on Hart Street),	15
Beverly, Mass. (beside railroad track),	3
Cohasset, Mass. (Barron's Island),	18
Hingham, Mass. (island in the millpond),	5

Taking the average of these results, we see that the total number of apparently living eggs has been decreased by introduction of the artificially developed Flacherie to about *14* per cent. This result is shown graphically in Figs. 4 and 5, where 1 per cent. is equal to 1 square, the cross-lined spaces representing the percentage of *dead* eggs.

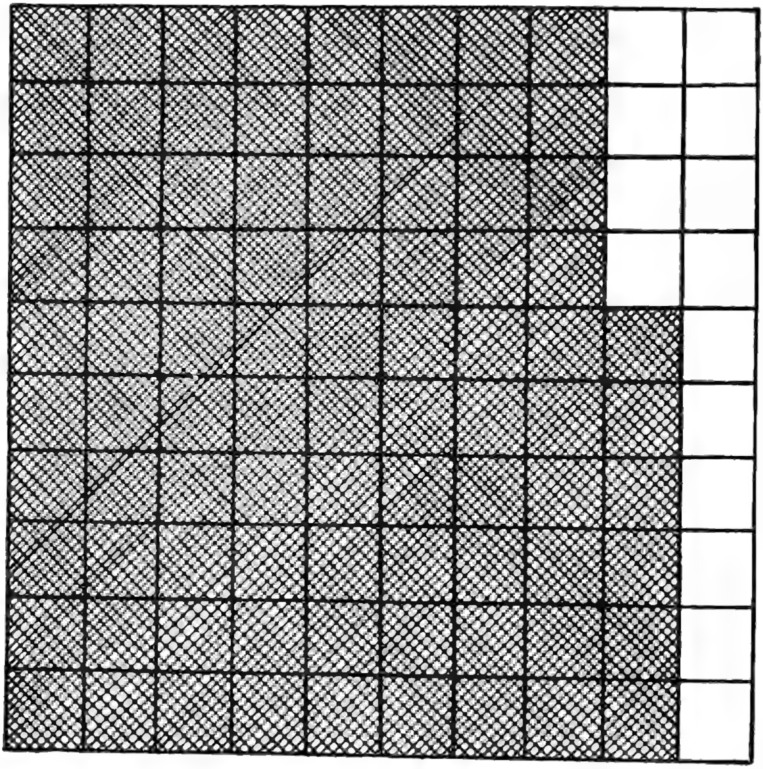

Fig. 5. — Diagram showing average percentage of living eggs after introduction of the disease.

Only those localities have here been tabulated on which we had complete data from the beginning to the end of the experiment.

V. Final Conclusions.

The foregoing experiments prove conclusively that Flacherie has an injurious influence upon the prosperity of the gypsy moth caterpillars, this influence varying according to the manner and time of the appearance of the disease. There was no difference noticed in the progress of the wilt which broke out naturally and that of the artificially developed Flacherie. The latter, however, is probably the more important factor, for with its help we may be able to introduce the disease among caterpillars of localities in which the wilt, perhaps, would not make its appearance naturally. The infection of a place with *sick* material only seems to be, as regards the " dying off " of the caterpillars, less favorable for the spread of Flacherie than with material which already contains a number of *dead* individuals. In selecting the localities in which the disease is to be introduced, it is unimportant whether the caterpillars of the gypsy moth are present in large or small numbers. It is true the wilt will get a stronger foothold and attain a greater virulence the larger the number of caterpillars. In places, however, which are not badly infested, the disease will also spread to the healthy caterpillars, as was shown by several of the experiments. According to the observations, we are almost inclined to believe that the direction of the wind plays an important rôle in spreading the disease. This opinion is strengthened especially by the observations made in Concord and West Bedford.

Wherever the naturally as well as the artificially developed Flacherie occurs the female caterpillars will always succumb to it more readily than the male. This may perhaps be due to the fact that they require a longer time to mature than the male caterpillars. If, at the flying period of the moth, we visit such a diseased locality, — one in which during the summer the caterpillars were quite plentiful, — we find ourselves surrounded by male moths, which to the superficial observer would indicate that the wilt had caused no considerable diminution. As soon, however, as we begin to search for adult females, we discover that they are present in a decided minority, and that they are by no means in the same large proportion to the male moths as in localities where the disease has not occurred among the caterpillars. The effective result, then, will be shown at the time of oviposition, in the decrease of the number and size of the fresh clusters, compared with those of the previous year. To be sure, this will not always be the case; for instance, in localities in which Flacherie appears very late. However, places infected early enough, always show as a result a diminution in the number of the fresh clusters, sometimes to 100 per cent. The reduced average size of the clusters also has a close connection with the wilt. Heretofore it has often, but erroneously, been supposed that small clusters were deposited by small female moths, which suffered during their caterpillar stages from lack of food. Certainly such cases are not rare, but the origin of small clusters is capable of yet another explanation. For instance, in localities in which there are few gypsy moth caterpillars, and where there is no lack of food, but where the wilt has worked, egg clusters are found which are no larger than a pea or a bean. Such clusters contain from 4 to 12 eggs, with embryos which are usually incompletely or not at all developed. In such localities it may often be recognized, from the volume of the abdomen, even of the freshly emerged female moths, which were little below the normal size, that the body contained only a small number of eggs. Also, in several cases the interior of the body was examined, and then it was found that the cause of the small circumference of the body was that the ovary was small. Females which had already oviposited and died were examined to see whether they contained more eggs in their bodies. Eggs were always found in females that had laid egg clusters which were only partly, or not at all, covered with hair. But there were sometimes found undeposited eggs in females which had completely covered the cluster with their abdominal hairs. All this must be taken in connection with the wilt, for female moths from healthy colonies deposit all the eggs they contain, as long as they are not interrupted at the time of egg laying, and it does not matter whether the individuals are large or small.

The most important point to be noticed is the fact that the clusters which are found in localities in which Flacherie operates among the caterpillars contain, on the average, a comparatively high percentage of dead eggs. Hence, Flacherie has a direct effect even upon the next generation. If, however, the number and the quality of the eggs in the female adult are affected by the wilt, is it not then possible that the disease goes directly over to the eggs? Certainly we have no direct proof of this at the present time, but we do know that Flacherie can be carried over from the caterpillar to the pupa, and from the pupa to the adult, and we have seen that the eggs in the ovary of females which come from infected colonies are influenced by the disease in regard to their number and vitality. In spite of the many investigations which have been made by celebrated bacteriologists in both the old and the new world, the carriers of the disease have not yet been determined. This shows what a difficult problem science has before it to solve. Although several scientists accept neither the heredity of the disease, nor believe that it can be carried over to the next generation, there are others (Pasteur, Fischer) who believe in its transmissibility. Perhaps the disease is carried over to the following generation through the adult female only, in a similar manner to the pébrine. Perhaps, moreover, the name Flacherie covers several diseases, which, it is true, make their appearance in the same manner in the infected individuals, but nevertheless are specifically distinct. One of these diseases may be restricted, indeed, to caterpillar and pupa only, while the other disease is carried over to the adult, and might possibly be inherited through the female organism by the descendants. It may be possible to throw some light on these complicated questions by breeding experiments, but only the investigations of the bacteriologist and pathologist can secure the final proof. It would be of the highest importance for the economic value of Flacherie if the inheritance of the disease could be definitely proved. If the wilt proves to be the direct cause for the "dying off" of many embryos of eggs from infected localities, death would be caused by the organisms of the disease themselves, and probably not be a result of the weak constitution of the female moth. The still living embryos of the same cluster will then contain, without doubt, at least partially, the carriers of the disease, which, according to their number and to the constitution of the embryo, will kill, early or late, the larva after it has hatched. Thus Flacherie will be carried again through the whole ontogeny of the descendants of those individuals which were originally infected by the disease. In this case the wilt would be hereditary, and it would have by far the greatest possible economic value and benefit. If, however, the "dying off" of several of the embryos is only a consequence of the weak condition of the female adult, which perhaps was slightly infected during the caterpillar stage, then of course the guaranty for the wilt is not yet given for the next generation. Among the hatching caterpillars there will always be a considerable percentage of weak individuals which thus possess from the beginning the necessary predisposition to the disease. If, then, the climatic conditions develop favorably for the disease, these weak caterpillars will be attacked first by the wilt, but as it increases in virulence it will attack the stronger and healthier individuals. If the climatic conditions are less favorable for the natural appearance of Flacherie, we hope the introduction of the artificially developed Flacherie in the respective localities will transmit the disease to the weak caterpillars. Then the disease will operate as though it had appeared naturally.

The existence of the wilt does not depend upon climatic conditions as soon as the disease is once established. It is true weather conditions will often be of great advantage in spreading the disease, but not likely to be of considerable harm. Hence, Flacherie, even if its nonheredity should be proved, is a factor of great importance to economic entomology. It will be advisable to work with the wilt against the gypsy moth in large wooded areas of all kinds, and it has the great advantage of cheapness, while the spraying with arsenate of lead or with other poisons is expensive. A very good scheme would be to furnish as many trees as possible with rings of tanglefoot in heavily infested forest districts, and not to kill the caterpillars after they are gathered together under the rings, but to assist in this manner the more rapid spread of the wilt, since the sick and weak individuals thus have a greater possibility of coming in contact with healthy caterpillars. The effect of this method was observed in one case during the summer of 1910. In company with the division agent, Mr. Worthen, I came in touch with a locality in Boxford where gypsy moth caterpillars were gathered together in considerable numbers under tanglefoot rings. It had been decided to kill the caterpillars with burning oil, but I dissuaded the men from doing this by giving as my opinion that the wilt would make its appearance in all probability in a few days. This assumption was right, for there was seen, after three days, the first signs of the disease, which then spread so quickly that in a few more days the caterpillars had succumbed.

Perhaps it might be worth while to work with the wilt in different ways from those in the experiments described. There is, for instance, the recapitulation of the experiments of 1909 on a large scale. Caterpillars which had been killed by Flacherie were mixed with water in different ways, and the mixture was then either sprayed upon trees or was painted as rings around the trunks. One or the other of these methods may prove to be valuable, but the expense will be quite high, while the use of the simple exposure method incurs but small expense. There might be mentioned still another point; Dr. E. Fischer of Zürich, the discoverer of the predisposition of caterpillars towards Flacherie, wrote me some time ago the following directions for developing Flacherie artificially in the field: cut some of the larger roots of a tree that is infested with a sufficient number of caterpillars, water frequently the ground around the cut surfaces and put into the trunk as much water as possible through a hole bored at an angle of about 45° to the base of the tree. By these means the same unhealthy food is produced on the tree as is otherwise obtained by the placing of twigs in water. It is certain that the wilt can be developed artificially in the manner just described, but such an experiment needs constant attention, and trees thus treated are, of course, destroyed.

I doubt whether the gypsy moth will ever become extinct in America, but the wilt will probably produce, first, a considerable reduction of the mass, and then it is to be hoped that the insect parasites and other natural enemies will contribute in diminishing the pest to a minimum. I am quite convinced that we can apply the wilt in a systematic manner to the benefit of our forests, and that in so doing we shall come considerably nearer to a solution of the problem of destroying the gypsy moth. In wooded areas mainly much more attention should be given in future to the wilt as an aid in combating the insect, while for street trees, garden trees, etc., which are more easily managed, the eggs and caterpillars of the gypsy moth may be removed according to established methods. The wilt should eventually reduce the pest to a condition in which it can be easily kept in check, and prevent serious outbreaks and damage.

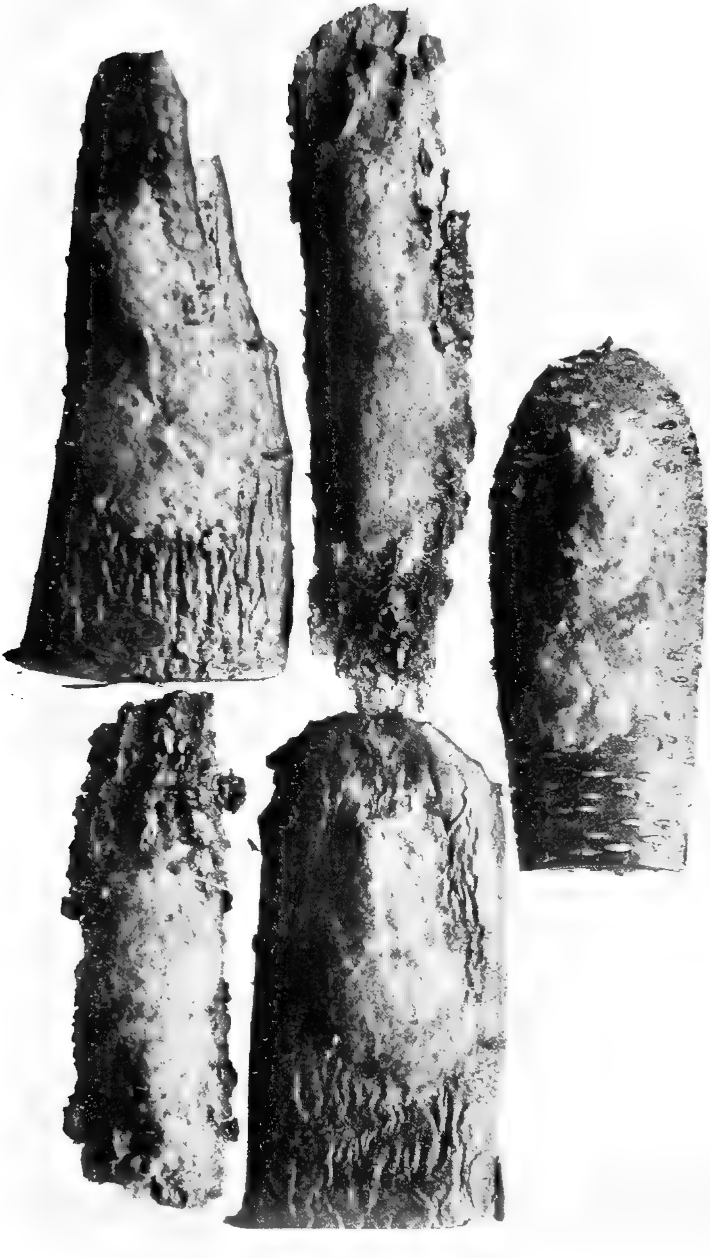

PLATE I. — Egg clusters from a healthy colony.

PLATE II.—Egg clusters from a colony where disease was introduced.

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L. O. HOWARD, Entomologist and Chief of Bureau.

INSECTS WHICH KILL FOREST TREES:

CHARACTER AND EXTENT OF THEIR DEPREDATIONS AND METHODS OF CONTROL.

BY

A. D. HOPKINS,

In Charge of Forest Insect Investigations.

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L. O. HOWARD, Entomologist and Chief of Bureau.

INSECTS WHICH KILL FOREST TREES: CHARACTER AND EXTENT OF THEIR DEPREDATIONS AND METHODS OF CONTROL.[a]

By A. D. HOPKINS,

In Charge of Forest Insect Investigations.

It has been conclusively demonstrated that certain species of insects are the direct or primary cause of the death of forest trees of all ages, and that from time to time they multiply to such an alarming extent that their depredations assume the character of a destructive invasion, which results in the death of a large percentage of the best timber over thousands of square miles.

There are many species of barkbeetles which prefer to attack matured and healthy trees, and there are many examples of whole forests of century-old trees that have perished from the girdling effect of the mines of the beetles, which are extended in all directions through the inner living bark on the main trunks of the trees. Indeed, we find among these bark-boring beetles the most destructive insect enemies of North American forests. Some notable examples of the depredations of these barkbeetles are given below.

The southern pine beetle.—In 1890–1892 a destructive invasion of the southern pine beetle extended from the western border of West Virginia through Maryland and Virginia into the District of Columbia, northward into southern Pennsylvania, and southward into North Carolina. In this area, aggregating over 75,000 square miles, a very large percentage of the mature and small trees of the various species of pine and spruce was killed by this beetle. In many places in West Virginia and Virginia nearly all the pine trees of all sizes on thousands of acres were killed, while shade and ornamental trees within the same area suffered the same as those in the forest. Since 1902 this barkbeetle has been more or less active in the Southern States from Virginia to Texas, and in some localities and during certain years it has killed a large amount of timber. Records of extensive destruction of timber in the Southern States are found dating back to the early part of the nineteenth century. This species may be considered one of the most dangerous insect enemies of southeastern conifers and, therefore, a constant menace to the pine forests of the Southern States.

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[a] Revised extracts from Bulletin No. 58, Part V, Bureau of Entomology, U. S. Department of Agriculture, 1909.

The eastern spruce beetle.—During the period between 1818 and 1900 there were several outbreaks of the eastern spruce beetle in the spruce forests of New York, New England, and southeastern Canada. This species caused the death of a very large percentage of the mature spruce over an area of thousands of square miles. In the aggregate many billions of feet of the best timber were destroyed. The larger areas of this dead timber furnished fuel for devastating forest fires, with the result that in most cases there was a total loss.

The Engelmann spruce beetle.—The Engelmann spruce beetle, with habits similar to the eastern spruce beetle, has from time to time during the past fifty years caused widespread devastations in the Rocky Mountain region to forests of Engelmann spruce, in some sections killing from 75 to 90 per cent of the timber of merchantable size.

The Black Hills beetle.—One of the most striking examples of the destructive powers of an insect enemy of forest trees is found in the Black Hills National Forest of South Dakota, where during the past ten years a large percentage of the merchantable timber of the entire forest has been killed by the Black Hills beetle. It is estimated that more than a billion feet of timber have been destroyed in this forest as the direct result of the work of this beetle. This destructive enemy of the western pine is distributed throughout the forests of the middle and southern Rocky Mountains region, where, within recent years, it has been found that in areas of greater or less extent from 10 to 80 per cent of the trees have been killed by it.

The mountain pine beetle and the western pine beetle.—The sugar pine, silver pine, western yellow pine, and lodgepole pine of the region north of Colorado and Utah, westward to the Cascades, and southward through the Sierra Nevadas are attacked by the mountain pine beetle and the western pine beetle, and, as a direct consequence, billions of feet of the timber have died. In one locality in northeastern Oregon it is estimated that 90 to 95 per cent of the timber in a dense stand of lodgepole pine covering an area of 100,000 acres has been killed within the past three years by the mountain pine beetle. Through many sections of the sugar-pine districts of Oregon and California, as the result of attacks by this same destructive barkbeetle a considerable percentage of the largest and best trees is dead.

The Douglas fir beetle.—The Douglas fir throughout the region of the Rocky Mountains from southern New Mexico to British Columbia has suffered severely from the ravages of the Douglas fir beetle, with the result that a large percentage of dead timber is found, much of which will be a total loss.

Three other species of beetles, having destructive habits similar to those above mentioned, depredate on the pines of New Mexico and Arizona, and still another has contributed greatly to the destruction of the larch throughout the northeastern United States and southeastern Canada.

The hickory barkbeetle.—Within the past ten years the hickory barkbeetle has caused the destruction of an enormous amount of hickory timber throughout the northern tier of States from Wisconsin to Vermont and southward through the eastern Atlantic States and into the Southern States as far as central Georgia.

The larch worm.—There are also many examples of widespread depredations chargeable to insects which defoliate the trees, thus contributing to their death. Notable among these are the depredations by the larch worm, which, during several extensive outbreaks since 1880, has killed from 50 to 100 per cent of the mature larch over vast areas in the northeastern United States and southeastern Canada. It is evident that the amount of merchantable-sized timber that has died as the result of defoliation by this insect will aggregate many billions of feet.

CONTROL OF BARKBEETLES WHICH KILL TREES.

The barkbeetles which kill trees attack the bark on the trunk and destroy the life of the tree by extending their burrows or galleries in all directions through the inner living bark. The broods of young grubs or larvæ develop within the inner bark, on which they feed. Those of some species develop to the adult stage within the inner bark and are exposed when the bark is removed, while those of other species transform to the adults in the outer corky bark and the larvæ are not exposed when the bark is removed. Some species have two or more generations in a season or annually, while others have but one, and in a few species it requires two years for a single generation to develop.

The barkbeetles of the genus Dendroctonus represent the most destructive enemies of the principal coniferous tree species of American forests, and at the same time are among the easiest of control. The general requisites for success are embodied in the following rules:

(*a*) Give prompt attention to the first evidence of a destructive outbreak, as indicated by an abnormal percentage of yellow or red topped dying trees, and especially when such trees occur in groups of ten or more or cover large areas; (*b*) secure authentic determination of the particular species of insect responsible for the trouble; and (*c*) take prompt action toward its control according to specific expert advice, published or otherwise, on the best method for the destruction of the necessary 75 per cent or more of the insects in the infested trees.

Some of the methods to be adopted to meet the requirements of various local conditions are as follows:

(1) Utilize the infested timber and burn the slabs during the period in which the broods of the destructive beetles are in the immature stages or before the developed broods emerge from the bark; or

(2) Fell the infested trees and remove the bark from the main trunk and burn the bark if necessary;[a] or

(3) Remove the infested bark from the standing timber and burn the bark when necessary;[a] or

(4) Immerse the unbarked logs in ponds, lakes, or streams, where the bark will remain soaked long enough to kill the insects; or

(5) Remove the unbarked logs or products to a locality where there are no trees liable to attack within a radius of 20 miles or more.

MAINTAINING CONTROL OF BARKBEETLES.

Future trouble of a serious nature from barkbeetles which kill trees can be prevented within a given forest or area of greater or less extent if an insect-control policy is adopted in connection with, or independent of, a fire-control policy by which groups of dying trees will receive similar prompt attention as that required for the prevention or control of forest fires.

In state and national forests.—In all forest reserves in which there is an organized force of rangers and fire wardens or patrols each officer should be furnished with instructions for the location of beetle-infested trees, and with equipment and directions for taking the necessary action whenever the conditions demand or warrant it.

In private forests.—Private forests should receive the same attention as public forests, but this is often far more difficult on account of intervening forests where the owners either can not or will not give the matter the required attention. While it may be advisable to have some laws to govern the treatment of timber infested with a dangerous pest when the owner refuses to take any action, such a law should apply only to the more extreme cases or as a last resort on authoritative advice. It is probable that in most cases legislation will not be necessary, and more ultimate good will result without than with strict laws, especially when it can be made clear to the owner that his personal interests demand that he take the proper action and that, when necessary, his neighbors will render assistance, as is done in the case of a forest fire.

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[a] If the broods develop to adults in the outer bark, it must be burned; if they develop in the inner bark and are exposed when the bark is removed, burning is not necessary. As a rule the burning of the tops to destroy the insects is not necessary.

Inaccessible areas.—There are yet large inaccessible areas in the East and West where it is not practicable or possible at present to control the depredations by these beetles and which must therefore be left to the same natural adjustment that has been going on in all forests from their beginning. While under such natural control much of the older matured timber will be lost it will usually be replaced by young growth, either of the same species of trees or of a different species, so that under normal conditions the forest will be perpetuated; but under exceptional conditions and combinations of detrimental influences, such as secondary insect enemies, fire, and drought, extensive areas may be completely denuded, never to be reforested under natural conditions. Therefore it will evidently not be very long before it will pay to adopt insect-control policies even in the areas that are inaccessible for profitable lumbering.

EXAMPLES OF SUCCESSFUL CONTROL OF BARKBEETLES.

The practicability of the advice based on the results of recent entomological investigations is demonstrated by a number of examples of successful control of depredations by destructive barkbeetles.

CONTROL OF THE EASTERN SPRUCE BEETLE.

The control of an alarming outbreak of the eastern spruce beetle in northeastern Maine in 1900 and 1901 was effected by the concentration of regular logging operations into the areas of infested timber and placing the logs in lakes and streams and driving them to the mills on the Androscoggin River. Thus, with little or no additional expense, there was a saving to one firm, according to its estimates, of more than $100,000.

CONTROL OF THE HICKORY BARKBEETLE.

The complete control of the hickory barkbeetle, which threatened the total destruction of the hickory trees on Belle Isle Park, at Detroit, Mich., in 1903, was effected by felling and removing the infested trees and converting them into merchantable products, all without cost to the park commission.

CONTROL OF THE BLACK HILLS BEETLE.

An extensive outbreak of the Black Hills beetle in the vicinity of Colorado Springs, Colo., in 1905–6, which was threatening the living pine timber of the entire section, was brought under control through the efforts of the private owners of forests and those of forest officials in the adjoining National Forests. It was accomplished by cutting and barking about 1,000 beetle-infested and beetle-killed pine trees. The cost of the operations was largely, if not entirely, covered by the utilized felled timber, although there was considerable unnecessary expense involved through the felling and barking of trees from which the beetles had emerged and from the unnecessary burning of the bark and tops.

The successful control of another serious outbreak of this beetle, in 1906, on an extensive private estate in southern Colorado, was effected through the efforts of the owners, who had some 500 infested trees felled and barked within the necessary period to destroy the broods. A large percentage, but not all, of the infested timber was thus treated. These operations were so successful that not a single infested and dying tree could be found when the area was inspected in 1908. In this, as in the other case, considerable unnecessary expense was involved in the burning of the bark and tops, but the value of utilizable timber was probably more than enough to pay all expenses. It is evident that in this case a destructive invasion was prevented.

The practicability of controlling this most destructive enemy of the pine timber of the central Rocky Mountain region, not only without ultimate cost but at a profit on the operations, was demonstrated on a large private estate and the adjoining Pike National Forest in north-central Colorado. An examination of the timber on this estate in the spring of 1907, by a ranger detailed from the Forest Service to work under instructions from the Bureau of Entomology, showed that the depredations by the beetle had been going on for the past ten years or more and had resulted in the death of the choicest timber to the extent of more than 800,000 board feet. About 65,000 board feet of timber was found to be infested by the beetle at the time of the examination. The owner was notified by the Bureau of Entomology of the dangerous character of the infestation and the required action for its control was recommended, but no action was taken. Another examination of the property was made in the fall of 1907, when it was found that the new infestation resulting from swarms of beetles that had been allowed to emerge from the old infested trees involved nearly four times as much timber, or 240,000 board feet. This alarming increase led to the prompt adoption of the recommendations by the owner and the Forest Service, and by May of the following spring (1908) the small number of trees on the National Forest was cut and barked, to kill the insects in the inner bark, and the 1,000 trees on the private estate were felled, the logs converted into lumber, and the slabs burned, which accomplished the desired purpose of destroying the broods of the beetle. The owner realized a sufficient revenue from the timber thus involved to cover all expenses and leave a net profit of over $1,200. Examination of the area in the fall of 1908 showed that this prompt and properly conducted effort to control the beetle was a complete success. Thus the average death rate of some 100,000 feet of timber annually during the past ten or more years was reduced to a minimum, at a net profit on the cost of doing it.

In addition to infested trees disposed of by the Forest Service in timber sales, 165 infested trees in one section of the Las Animas National Forest were cut and barked in May and June, 1908, at a direct cost of $177.50, and at the same time a considerable amount of infested timber was disposed of by sale in the Wet Mountains section of the San Isabel National Forest. This had a decided effect in checking the ravages of the beetle in both of these forests and it was followed up in the latter forest the next spring (1909) by the proper disposal of over 1,000 infested trees by free use, ranger labor, and direct expenditure of funds appropriated by the Forest Service. According to the forest supervisor's report, 80.7 per cent of the infested trees were treated, ranging from 70 per cent to 92.5 per cent on the five units of infestation; 795 trees were treated (535 barked, and 260 felled and bark scorched) at the expense of the Forest Service, including salary and expenses of rangers. The cost per tree was about 60 cents for felling and barking, and ranged from 52 to 78 cents for felling and scorching the bark on the infested trunks. The average cost per tree was 68.2 cents. Six hundred and twenty-six trees were treated by temporary labor, at an average cost of 61 cents per tree under contract at $1.50 to $2 per hundred feet in length of trunk peeled. The same rate was allowed for scorching the infested bark instead of removing it. Two hundred and seventy-five trees were treated under administrative use without cost to the Forest Service.

In September, 1909, a very thorough examination was made of the timber in and adjacent to the areas involved in the control operations, and it was found that the thorough, prompt, and proper manner in which the instructions of the Bureau of Entomology were carried out in this case resulted in bringing the beetle under complete control. Only 7 trees had been successfully attacked by the beetles which had emerged from some 400 infested trees which were not cut during the previous control operations. Over 100 trees were found that had been attacked by the beetles, but, owing to the limited number of the latter, the trees were able to resist them and recover.

It is now evident that the control operations carried on in southern Colorado during the past three years, on the Trinchera estate near Fort Garland in 1906, in the Las Animas National Forest and Wet Mountains section of the San Isabel National Forest in 1908, and the more extensive work in the latter area in 1909, had a far-reaching effect in bringing the Black Hills beetle under control within the forested areas of southern Colorado, and that the loss of timber from this source, amounting to an average of some 300,000 board feet annually, has been reduced to a minimum.

These results mark the most important events in the control of forest insects in this country and serve as striking demonstrations of what can be accomplished when cooperative efforts are directed along the proper lines and based on the results of scientific investigation. The attainment of these results was due to three important factors: First, a knowledge of the insects on which the recommendations by the Bureau of Entomology were based; second, a knowledge of local conditions and requirements and of the habits of the insects in relation to newly infested trees, which enabled a forest ranger to locate the infested trees and give instructions to the forest officials in regard to such locations and the essential details in the recommendations; third, a prompt and proper practical application by the Forest Service of the recommendations according to improved forestry methods to meet the requirements of a forestry problem.

Ten years ago it would have been absolutely impossible to have accomplished this result, owing to the utter lack of knowledge of the first two of these features, and at the present time it would have been impossible without the assistance of the Forest Service.

CONTROL OF THE MOUNTAIN PINE BEETLE.

A very threatening outbreak of the mountain pine beetle was located, in 1909, in the Snowy Mountains section of Montana, adjacent to and within the Jefferson National Forest, involving, at the time, more than 1,500 infested and dying trees. The infestation included timber on the National Forest, public domain, state lands, and private lands, thus involving a complication of federal, state, and private interests with which to deal in securing the required action. The case was so successfully managed that an agent of the Bureau, Mr. Josef Brunner, was placed in complete charge to carry out the recommendations and instructions of this Bureau, and, through the aid of the Forest Service, state officials, and private owners, 1,355 infested trees were cut and barked to kill the broods of beetles. The cutting was started about June 15, 1909, and was completed about July 24 of the same year. Four hundred and twenty-two trees were cut at private expense, 783 at the expense of the Forest Service, and the remainder by local owners. The average cost for felling and removing the bark from the infested portion of the trunk was 30 cents per tree.

Early in December, 1909, a careful examination was made of the area for evidence of new infestation. It was found that, while some 56 trees had been attacked by the mountain pine beetle, the broods were being destroyed by woodpeckers and other natural enemies, and that, therefore, the efforts to control the beetle depredations were a complete success.

The examples of practical control given above have demonstrated at least two important facts: One, that extensive outbreaks by two of the most destructive bark-beetle enemies of the pine timber of the Rocky Mountain forests can be controlled at moderate expense when the timber is not accessible for utilization, or at a profit whenever the conditions are favorable for the utilization of the infested timber; the other, that the essential details of the recommendations and expert advice, based on the results of scientific research, can be successfully applied by a manager of a private forest or by the rangers of national and state forests. Furthermore, these results indicate quite conclusively that the widespread depredations in the Black Hills National Forest could have been prevented with very little expense to the Government if the matter had received prompt attention in 1901, when the first investigations were made and essentially the same recommendations submitted as in the cases mentioned. Failure to do so was through the lack of public appreciation of the importance of the problem at the time and the lack of sufficient authority and funds later. Therefore the outbreak was allowed to extend beyond practical control, and in consequence a large percentage of the timber of the entire National Forest has been killed. There were then no forcible examples of the practical value of recommendations based on scientific research, and no other argument was effective in arousing public interest in the threatening character of the outbreak or confidence in the advice and methods of control. Now that the practicability of controlling the most destructive insect enemies of North American forests has been demonstrated, this should lead to a more general interest in the subject and confidence in the results of scientific research as a basis for success in practical application.

Approved:
JAMES WILSON,
Secretary of Agriculture.
WASHINGTON, D. C., *October 7, 1910.*

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BUREAU OF ENTOMOLOGY—CIRCULAR No. 129.

L. O. HOWARD, Entomologist and Chief of Bureau.

INSECTS IN THEIR RELATION TO THE REDUCTION OF FUTURE SUPPLIES OF TIMBER, AND GENERAL PRINCIPLES OF CONTROL.

BY

A. D. HOPKINS,

In Charge of Forest Insect Investigations.

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United States Department of Agriculture,

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L. O. HOWARD, Entomologist and Chief of Bureau.

INSECTS IN THEIR RELATION TO THE REDUCTION OF FUTURE SUPPLIES OF TIMBER, AND GENERAL PRINCIPLES OF CONTROL.[a]

By A. D. HOPKINS,
In Charge of Forest Insect Investigations.

Insects not only reduce future supplies of timber by killing the mature trees and destroying the wood of timber that is inaccessible for utilization, but through injuries inflicted upon trees during the flowering, fruiting, germinating, seedling, and sapling periods of early growth they prevent normal reproduction and development.

INTERRELATIONS OF FOREST INSECTS AND FOREST FIRES.

Investigations conducted by the writer and assistants in all sections of the country during the past ten years indicate to them quite conclusively that the average percentage of loss of merchantable timber in the forests of the entire country to be charged to insects during a five or ten year period is infinitely greater than most people realize.

Losses from forest insects.—The writer estimates that for a ten-year period the average amount of timber in the forests of the entire country killed and reduced in value by insects would represent an average loss of $62,500,000 annually.[b]

It has been estimated that the Black Hills beetle killed approximately 1,000,000,000 feet B. M. of timber during a period of ten years, which at $2.50 per thousand would amount to an average of $250,000 annually. This is merely one example of very destructive depredations by a single species of barkbeetle in a single National Forest.[c]

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[a] Revised extracts from Bulletin No. 58, Part V, Bureau of Entomology, United States Department of Agriculture.

[b] *Losses from forest fires.*—It has been estimated that "on the average, since 1870, forest fires have yearly cost $50,000,000 in timber." (Cleveland, T., jr., Circular 167, Forest Service, United States Department of Agriculture, p. 3.)

[c] It has been estimated that the losses of timber from forest fires on all of the National Forests of the United States from 1905 to 1908, inclusive, average only $165,062 annually. (Cleveland, T., jr., Yearbook United States Department of Agriculture for 1908, p. 541.)

Prof. Lawrence Bruner, state entomologist of Nebraska, at a meeting of the American Association of Economic Entomologists, held at Baltimore, Md., in December, 1908, spoke as follows: "I can agree with Doctor Hopkins that the insects are far more important in destroying our forests than fires."

Insect-killed timber as fuel for fires.—It has often happened that after insects have killed the timber over extensive areas the standing and fallen dead trees furnished fuel for great forest fires which have not only destroyed or charred the dead timber but killed the living timber and reproduction and swept on into adjacent areas of healthy timber. Indeed, abundant evidence has been found during recent investigations to indicate that some of the vast denuded areas in the Rocky Mountains and other sections of the country are primarily due to widespread devastation by insects, and that subsequent fires destroyed the timber and prevented reproduction.

It is also evident that a considerable percentage of dead timber, and especially that found in coniferous forest regions, which has generally been believed to have been fire-killed is a result of primary attack by insects. This has been demonstrated in many cases by the pitch-marked galleries of the destructive barkbeetles on the surface of the wood of the old dead trees which had escaped subsequent fires.

Fire-killed timber injured by insects.—It is true that a vast amount of timber has been killed outright or has died as the direct result of forest fires, but in almost every case observed insects have contributed to a greater or less extent to the death of recently fire-injured trees which might otherwise have recovered, and especially to the rapid deterioration of the wood of a large percentage of the injured and killed trees. It is evident that in some cases fire-scorched and fire-killed timber has contributed to the multiplication of one or more of the insect enemies destructive to living timber, and thus the injury started by the fire may have resulted in a destructive outbreak of beetles. However, it is evident that this has happened only when the destructive beetle was already present in abnormal numbers in the forest surrounding the fire-swept area. Therefore, *it is believed that injuries by fire are not as a rule an important factor in contributing to subsequent depredations by barkbeetles.* Such fires, however, contribute to the multiplication of the insects which depredate on the bark and wood of dying and dead trees, so that in forested areas where fires are frequent the damage to the wood of such trees is more severe, and fewer injured trees recover on account of the abundance of secondary barkbeetle enemies which do not, as a rule, attack and kill living timber.

Destruction of insects by fire.—There is another important feature in the relation of insects and fire, in which the fire contributes to the destruction of the principal barkbeetle enemies of the living timber.

This happens when the fire burns the timber while it is infested, thus effectually destroying the broods of the insects. It is perfectly plain that the dying and dead foliage of the beetle-infested trees and the dead bark on the trunks would contribute to the spreading of crown fires and thus the bark on the entire infested trunks would be sufficiently scorched to kill the insects. Therefore, complete fire control may easily contribute to more extended depredations by insects on the living timber, thus increasing, rather than diminishing, the need for insect control. However, the setting of fires or permitting them to burn for the purpose of combating insects should never be undertaken or permitted.

Durability of insect-killed timber.—Some of the matured larch trees which evidently died as a result of defoliation by the larch worm between 1881 and 1885, and which had escaped subsequent depredations by fire and wood-boring insects, were found by the writer in 1908 to be standing and sound enough to be utilized for railroad ties and many other purposes. Under similar conditions the heartwood of red spruce and white pine in the East, of Engelmann spruce in the Rocky Mountains, and of Douglas fir in the Northwest coast region have been found by the writer to be sound enough for profitable utilization for pulp wood, lumber, fuel, and other purposes from twenty to thirty years after it had been killed by insects or fire. Thus it is shown that timber killed by insects and fire would be available for utilization for many years were it not for injuries through the secondary attacks of wood-boring insects and the destruction of insect-killed timber by forest fires.

INTERRELATION OF FOREST INSECTS AND FOREST FUNGI.

Decay following injury by insects.—It is well known that the burrows in the bark and wood of living and dead trees and in the crude and finished products often contribute to the entrance of bark and wood decaying fungi. Deterioration and decay are thus far more rapid than would otherwise be possible. It is also known that trees injured and dying from primary attack by parasitic fungi are attractive to certain insects which breed in the bark and wood of sickly and dying trees, and that certain other complicated troubles affecting forest trees are the result of an intimate interrelation and interdependence of insects and fungi. There can be no doubt, however, that certain species and groups of both insects and fungi are independently capable of attacking and killing perfectly vigorous and healthy trees.

SUMMARY AND ESTIMATES RELATING TO CHARACTER AND EXTENT OF INSECT DAMAGE.

The killing of trees by insects; the damage by them to the wood of living, dying, and dead timber; the destruction of insect-killed timber by subsequent forest fires; the damage to fire-killed timber by insects; and the damage from decay resulting from insect injuries to the wood, have all been more or less continuous for centuries and are still going on in the forest and woodland areas of this country.

While these depredations are not always evident or important in all forests or localities, yet almost every year, somewhere in the forests of the country, there are widespread depredations.

In every forest and woodland there is an ever present but inconspicuous army of insects which require the bark, wood, foliage, and seeds of the various tree species for their breeding places or food. Thus, the accumulated but inconspicuous injuries wrought during the period required for the growth of a tree to commercial size go far toward reducing the average annual increment below the point of profitable investments.

The accumulated damage to crude, finished, and utilized products reduces the profits of the manufacturer, increases the price of the higher grades to the consumer, and results in an increased drain on the natural resources.

In any attempt to estimate in *feet, board measure*, or *dollars*, the extent of losses or waste of timber supplies caused by insects there are many conflicting factors which contribute to the difficulty of arriving at accurate conclusions. The published information concerning the amount in board feet of standing timber in the country is admittedly only an estimate, as are also the published data relating to average stumpage value. The published statistics relating to the amount and value of forest products are of course more accurate, but until more complete data can be furnished by the forest experts on the various complicated phases of forest statistics any figures given by the forest entomologist relating to the value of timber and commercial products destroyed or reduced in value by insects must be considered on the same basis as the other estimates, and as the best that can be presented on available evidence.

Standing timber killed and damaged by insects.—When we consider the amount of standing merchantable timber killed by insects and the amount of standing timber, living, dying, and dead, which has been reduced in quantity and value through their agency during a ten-year period, we would estimate that such timber represents an equivalent of more than 10 per cent of the quantity and stumpage value of the total stand of merchantable timber in the United States at any given time.[a] A certain percentage of such timber is a total loss because of the impossibility of utilization; but in some cases a greater or less percentage can be, and in some cases is, utilized within the period in which it is of sufficient value to yield a profitable return on the cost of logging and manufacture, although its value is greatly reduced.

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[a] The estimate of the area and stand of the present forests of the United States, as given in Circular 166 of the Forest Service, page 6, is two trillion five hundred billion feet (2,500,000,000,000) board measure. The average stumpage value has been given as $2.50 per one thousand feet b. m., making a total value of the standing merchantable timber of $6,250,000,000. Ten per cent of this amount would be $625,000,000, as the amount to be charged to in-

Reduction in the Nation's wealth.—When we consider the forest resources both in merchantable timber and young growth as an important asset of the Nation's wealth; as representing a given value to the people for direct utilization; as a cover to the soil for protection of the land from erosion; as protection of headwater streams and of game; and as contributing to the æsthetic value of health and pleasure resorts, it would be difficult indeed to estimate the amount or percentage of loss of timber or the reduction in the land values, in each case, chargeable to insects. It is plain, however, that in the aggregate it is considerably greater than when estimated on stumpage values alone.

Reduction in cash revenue.—When we consider the problem from the standpoint of direct utilization we can estimate the annual loss on a basis of mill values; but here again we meet with complications, since much of the damaged material is left standing or is discarded in the woods or at the mill without measurement. Therefore we are left to judge from our observations and knowledge of the general conditions as regards dead and damaged timber found in the forests of the country, and the information from lumbermen in different sections, as to the percentage of loss from defective timber. On this basis we can estimate that the amount of insect-killed and damaged timber left in the woods, plus the reduction in value of that utilized, to be charged to insects is not far from an equivalent of 10 per cent of the value of the annual output of forest products of all kinds, in the rough. The total value of the forest products of the United States in 1907 is given as $1,280,000,000; the losses from insect depredations would therefore represent an annual loss in a cash value of more than $100,000,000.

Reduction in value of finished and commercial products.—When we consider the aggregate loss to the manufacturers of the finished products, to the trade, and to the consumer from insect injuries to the wood, it is evident that it amounts to many millions of dollars in addition to the estimated loss of crude products, or at least 3 per cent of the mill value.

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sects for a ten-year period, or an average of $62,500,000 annually. As an example, it has been estimated that over 1,000,000,000 feet b. m. of timber was killed by the Black Hills beetle in the Blacks Hills National Forest within a period of ten years. This, at $2.50 per one thousand feet stumpage, would be an average of $250,000 annually in a single forest of 1,294,440 acres.

METHODS OF PREVENTION AND CONTROL.

The results of extensive investigations and of practical applications of the knowledge gained during recent years have demonstrated that some of the most destructive insect enemies of American forests and of the manufactured and utilized products can be controlled, and serious damage prevented, with little or no ultimate cost over that involved in forest management and business methods.

There are, of course, certain insects and certain injuries which, under present conditions and available information, can not be controlled or prevented, but it is very evident that if the information now available through the publications of the Department of Agriculture and through direct correspondence with its experts is properly utilized in the future it will result in the prevention of at least 30 per cent of the estimated annual waste of forest resources that has been caused by insects within recent years, and thus contribute greatly to the conservation of forest resources.

General Principles of Control.

The ordinary spraying and similar methods employed in dealing with fruit and shade tree insects are, of course, not available for practical application in the case of forest trees. But there are other and less expensive methods of accomplishing the desired results.

In all efforts to control an outbreak or prevent excessive loss from forest insects it should be remembered that as a rule it is useless to attempt the complete extermination of a given insect enemy of a forest tree or forest product. Experience has demonstrated that it is only necessary to reduce and weaken its forces 75 per cent or more. It can not then continue an aggressive attack, but must occupy a defensive position against its own enemies until conditions resulting from avoidable negligence and mismanagement by the owners of the forests and manufacturers of forest products favor its again becoming destructive. Forest insects can thus be easily kept under control by good management.

The desired control or prevention of loss can often be brought about by the adoption or adjustment of those requisite details in forest management and in lumbering and manufacturing operations, storing, transportation, and utilization of the products which at the least expenditure will cause the necessary reduction of the injurious insects and establish unfavorable conditions for their future multiplication or continuance of destructive work.

It is, however, of the utmost importance that any adjustment or modification in management or business methods should be based on expert technical knowledge or advice relating to the species, habits, life history, and natural enemies of the insects involved and the essential features of the methods for their control. This should be supplemented by expert knowledge or advice on the principles of technical and applied forestry in the proper management, care, and utilization of the forest and its resources, and still further supplemented by practical knowledge and experience relating to local conditions and facilities favorable and unfavorable for success in practical applications according to the recommended method or policy of control.

As has been shown, the mature or merchantable timber is the most susceptible to injury or death from the ravages of insects. Therefore, considered from the standpoint of insect control and the prevention of one of the greatest items of loss, it is important that such matured timber should be utilized before it begins to deteriorate, or before it reaches the stage of unprofitable growth.

For the greatest success in dealing with forest insects, it must be recognized that there are certain features in the habits and seasonal history of each species which differ to a greater or less extent from those of all other species, even of the same genus; that there are certain features in the characteristics of the various species of trees which differ from those of all other species; and that as a rule it is the technical knowledge of these peculiar features or characteristics of the trees and their enemies which furnishes the clew to successful methods of control.

There are also many peculiar features in the prevailing conditions in different localities, some of them favorable, others unfavorable, for the practical application according to a given method, so that while certain general advice may apply in a broad sense and be available for utilization by the practical man, whether owner, manager, or forester, without further advice, it is often necessary to diagnose a given case before specific expert advice can be given as to the exact cause and the most effective method or policy to be adopted, just as a physician must diagnose a case of illness or injury before prescribing the required treatment for his patient.

Therefore, in a consideration of the problem as to how far the waste of forest resources caused by insects can be prevented and how far the damaged timber can be utilized, we will attempt to give only general statements based on the results of our observations relating to some of the principal kinds of loss discussed in Circulars 125 to 128, inclusive, of this Bureau. In addition, we will consider in this circular the utilization of natural enemies of injurious insects and the utilization of waste caused by insects.

UTILIZATION OF NATURAL ENEMIES AND FACTORS IN THE CONTROL OF INJURIOUS INSECTS.

Were it not for the natural checks and natural factors of control of some of the more destructive insect enemies of forest trees and forest products, artificial control would in many cases be impossible, and the depredations would evidently be far more continuous and complete. These natural factors in the control of the depredating insects consist of parasitic and predatory insects, diseases of insects, birds, adverse climatic conditions, etc. While one or more of these beneficial factors exert a continuous and powerful influence toward the prevention of a much greater waste of forest resources, it has been repeatedly demonstrated that they can not be depended on to prevent widespread devastations or to otherwise work for the best interests of the private or public owner by protecting the best trees and the best tree species. The insects and birds which prey upon the depredating insects also have factors to contend against, consisting of insects, birds, diseases, and climatic conditions. Therefore under normal conditions the tendency is toward the preservation of a balance between the warring factors, but frequently the enemies of the trees get the ascendancy and take on the character of an invasion, which may continue for two or three or even ten years before the balance is again adjusted through the influence of the natural enemies or diminished food supply. Thus a vast amount of timber or of a given forest product may be destroyed before the factors of natural control can prevail.

It is evident that the most effective utilization of the agencies of natural control will be through the alliance with them of the owner of the forest by his efforts toward an artificial reduction of the enemies of the trees rather than by efforts to make the natural enemies of the injurious insects his allies through artificial introduction or dissemination. The former is accomplished by the adoption of methods of combating the invaders which will reduce and weaken their forces below their power of prosecuting aggressive movements and attacks, or, as previously stated, to reduce their numbers to the point where they must occupy a defensive position against their natural enemies and be dependent for their supplies of food and breeding places upon that furnished through avoidable mismanagement of the forests and manufacturing operations. Thus the owner of the forest can contribute greatly toward the preservation of a balance which will be to his material benefit. On the other hand, he may in the future, as in the past, contribute greatly to the multiplication of the depredating insects and to greatly increased losses caused by them through neglect or a disregard of available information on the fundamental principles of insect control in the management of forests and manufacturing enterprises.

BENEFICIAL INSECTS.

The beneficial insects comprise those which are internal or external parasites of the immature or mature stages of the injurious insects, and predators which feed on the young or adults of insects either before or after they make their attack on the trees or products. These two beneficial factors are doubtless far more effective in the long run than any other agencies of natural control. Yet they, in combination with all other factors, can not be relied upon to render continued and efficient control. They can, however, be relied upon to respond to artificial assistance in reducing the numbers of the depredators.

BENEFICIAL DISEASES OF INSECTS.

It is very evident that the parasitic fungi and bacteria which sometimes cause epidemics among injurious insects often exert a powerful influence toward the control of extensive outbreaks or invasions of insect enemies of forests. Indeed, it appears that the greatest service rendered by this class of natural enemies is in the frequent sudden appearance of an epidemic which kills off a destructive species of insects after the latter has increased to such numbers and extended its depredations over such vast areas as to be far beyond the control of man or his insect and bird allies. Numerous examples of this kind of natural control are found in the sudden ending of widespread depredations by various species of caterpillars and sawfly larvæ which defoliate deciduous and coniferous trees. As a rule, however, the beneficial effects of the diseases of insects prevail only after the injurious insects have increased to excessive numbers. Therefore this factor of insect control can not be depended upon to hold the insects in check or prevent outbreaks. The fact, however, that it operates on a class of insect enemies of the forest (defoliators) which at present can not be controlled by any known artificial methods renders the services of the diseases all the more valuable.

It is believed that with further knowledge of nature's method of propagating, perpetuating, and disseminating the diseases which cause epidemics among insects they may be utilized more or less successfully through artificial propagation and dissemination to prevent threatened invasions of defoliating insects.

BENEFICIAL BIRDS.

It is very evident that certain kinds of birds, such as woodpeckers, render valuable service toward the natural control of destructive bark and wood boring insects. They appear to render the greatest service, however, where but few trees are being killed or injured, because their concentrated work on such trees may contribute toward the prevention of an abnormal increase of the insects. They also render some service as allies of the other beneficial factors which assist in artificial control. It is evident, however, that where many hundreds or thousands of trees are being killed the comparatively limited number of birds in any forest under the most favorable conditions could have little or no beneficial effect. Therefore, while the birds should be classed among the valuable friends of the forest, and should be protected, it is plain that they can not, even with the utmost protection, be relied upon to protect the forest against destructive ravages of insects.

We must remember, in this connection, that there are complicated interrelations between birds, injurious insects, and beneficial insects which do not necessarily operate to the benefit of the forest. In fact, it may sometimes be quite the reverse. Therefore, in order to derive the greatest benefit from the conflict between the birds, the insect enemies of the trees, and the insect friends of the trees, we must utilize our knowledge of the factors which are contributing toward the preservation of a balance, so that whenever the enemies of the forest threaten to get beyond natural control we may enter the field through artificial means and endeavor to force them back to their normal defensive position.

BENEFICIAL CLIMATIC CONDITIONS.

The benefits to be derived from climatic conditions which are detrimental or destructive to insect enemies of the forest, while sometimes very great, are necessarily unreliable, and thus can not be depended upon to assist in artificial control. In fact, the very condition which may contribute to the destruction of one depredator may favor the multiplication of another.

UTILIZATION OF WASTE CAUSED BY INSECTS.

When we come to consider the vast amount of standing timber in the forests of the country which has been injured or killed by insects, and will go to waste if it is not utilized within a limited period, we realize that there are great possibilities in its utilization as a means of preventing the reduction of future supplies of living healthy timber. It is all the more important that the insect-infested timber should be utilized, because in so doing we can contribute more perhaps than in any other way to the reduction of the insects to or below their normal numbers, and thus provide against serious injury in the future, as well as to the maintenance of control.

Approved:
JAMES WILSON,
Secretary of Agriculture.
WASHINGTON, D. C., *October 7, 1910.*

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United States Department of Agriculture,

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

INSECT INJURIES TO THE WOOD OF LIVING TREES.[a]

By A. D. HOPKINS,
In Charge of Forest Insect Investigations.

It has been determined that insects of a certain class attack the wood and bark of living timber and that, while they do not contribute materially to the death of the trees or give much external evidence of their presence, they produce wounds in the bark and wormhole and pinhole defects in the wood which result in a depreciation in commercial value amounting to from 5 to 50 per cent. These defects in the wood are not detected until after the trees have been felled and the logs transported to the mill and converted into lumber. Thus to the actual damage to the lumber is added the expense of logging and manufacture of the defective, low-grade material, much of which must be discarded as worthless culls.

The oak timber worm.—One of the most destructive of the class of depredators just mentioned is the oak timber worm. It enters the wood of the trunks of living trees through wounds in the bark and at the base of broken or dead branches and extends its "pinhole" burrows in all directions through the solid heartwood. The losses occasioned by this insect in the hardwood forests of the eastern United States are enormous and usually affect the wood of the finest examples of old trees.

The chestnut timber worm.—The chestnut throughout its range is damaged in a like manner by the chestnut timber worm. Practically every tree of merchantable size is more or less affected, and a large percentage is so seriously damaged that the product is reduced to that of the lowest grade. It is estimated that the reduction in value of the average lumber product at any given time is not far from 30 per cent, thus involving extensive waste and an increased drain on the forest to supply clear lumber. This insect also attacks the oaks, and especially the red oak, the older trees of which are often as seriously damaged as are the chestnut.

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[a] Revised extracts from Bulletin No. 58, Part V, Bureau of Entomology, U. S. Department of Agriculture. 1909.

Carpenter worms.—The oaks, especially the white oak and the red oak, are seriously damaged by carpenter worms of the genus Prionoxystus. The holes made by these insects through the heartwood of the best part of the trunks are sometimes 1.5 inches in diameter one way by 0.75 inch the other, thus causing serious damage to the wood. These, with other large wood-boring beetle larvæ, sometimes infest the top part of the trunk and the larger branches of oak trees, where their continued work results first in the dead and so-called "stag-horn" top and subsequently in broken, decayed, and worthless trunks.

Ambrosia beetles.—One of the commonest defects in white oak, rock oak, beech, whitewood or yellow poplar, elm, etc., is that known to the lumber trade as "grease spots," "patch worm," and "black holes." This defect is caused by one of the timber beetles or ambrosia beetles, which makes successive attacks in the living healthy sapwood from the time the trees are 20 or 30 years old until they reach the maximum age. Thus the black-hole and stained-wood defect is scattered all through the wood of the best part of the trunks of the trees. The average reduction in value of otherwise best-grade lumber amounts, in many localities, to from 25 to 75 per cent. The defect is commonly found in oak and elm furniture and in interior hardwood finish in dwellings and other buildings.

The locust borer.—The locust, as is well known, suffers to such an extent from the ravages of the locust borer that in many localities the trees are rendered worthless for commercial purposes or they are reduced in value below the point of profitable growth as a forest tree; otherwise this would be one of the most profitable trees in the natural forest or artificial plantation and would contribute greatly to an increased timber supply.

Turpentine beetles and turpentine borers.—While the softwood trees, or conifers, suffer far less than the hardwoods from the class of enemies which cause defects in the living timber, there are a few notable examples of serious damage. There is a common trouble affecting the various species of pine throughout the country known as basal wounds or basal fire wounds. It has been found that a large percentage of this injury to the pine in the States north and west of the Gulf States and in the Middle and South Atlantic States is caused by the red turpentine beetle and in the Southern States by the black turpentine beetle. These beetles attack the healthy living bark at and toward the base of the trunks of medium to large trees and kill areas varying in size from 1 to 10 square feet. These dead areas are subsequently burned off by surface fires and are then generally referred to as fire wounds. The further damage to the exposed wood by successive fires, decay, and insects often results in a total loss of the best portion of the tree, or a reduction in value of the lower section of the trunk of from 10 to 50 per cent. These and similar wounds in the bark of trees, including those caused by lightning and by the uncovering and exposure of the wood in turpentining, offer favorable conditions for the attack of the turpentine borer, the work of which, together with that of two or three others with similar habits, is very extensive, and causes losses amounting to from 10 to 50 per cent of the value of the wood of the best part of the trees thus affected.

The white pine weevil.—The abnormal development of white pine trees as the result of successive attacks on the terminals of the saplings and young trees by the white pine weevil is an element of loss of considerable importance, especially in mixed stands and in open pure stands of this timber. The value of such trees is reduced from 20 to 50 per cent below those of normal development, and there is an additional loss from the effect of their spreading branches or crowns in the suppression or crowding out of trees which would otherwise occupy the space thus usurped.

There are many other examples of insects which damage the wood and bark of living trees, but those mentioned should be sufficient to demonstrate the importance of insects in this relation.

CONTROL OF INSECTS WHICH CAUSE DEFECTS IN LIVING TIMBER.[a]

The class of insects which cause defects in the wood of living timber can be controlled to a greater or less extent, depending upon local conditions, and a large percentage of the losses prevented through the adoption of certain requisite details in forest management, among which the following are especially important:

(1) The utilization of all of the defective and infested timber that will pay expenses for manufacture into merchantable products, such as lumber, cordwood, etc.

(2) The burning of infested timber and waste material not available for use, including dead standing and fallen timber, to remove the breeding places of insects like the oak timber worm and the chestnut timber worm, which go from the dead to the living timber.

(3) The prevention of wounds of any kind in the bark of living trees.

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[a] For methods of controlling the locust borer and white pine weevil, see Circulars 83 and 90, respectively, of the Bureau of Entomology, U. S. Department of Agriculture.

(4) The prevention of future losses by the practice of improved forestry methods to eliminate favorable conditions for injury and contribute to a perpetual supply of vigorous, healthy timber to be utilized before it passes the stage of profitable increment.

It should be remembered that the different species of insects which cause defects in the wood of living timber require different details in the methods of control, and that special cases, special local conditions, and details in business methods and requirements determine which one of the available methods should be adopted.

It should also be remembered that in the more important cases much loss of time and money may be prevented and the best success attained by first securing some authoritative advice on the insects involved and the specific requirements for the control work.

Approved:
JAMES WILSON,
Secretary of Agriculture.
WASHINGTON, D. C., *October 7, 1910.*

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United States Department of Agriculture,

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

INSECT INJURIES TO THE WOOD OF DYING AND DEAD TREES.[a]

By A. D. HOPKINS,
In Charge of Forest Insect Investigations.

Timber dying from insect attack and other causes, including fire, disease, storms, etc., is attacked by certain wood-boring insects which extend their burrows through the sound sapwood and heartwood, and thus contribute to the rapid deterioration and decay of a commodity which otherwise would be available commercially during periods of from one to twenty years or more after the death of the trees, depending on the species of trees and on the character of the product desired. This loss often amounts to from 25 to 100 per cent during the period in which the dead timber would otherwise be almost as valuable as if living.

CONIFEROUS TREES.

Sawyers.—One of the most striking examples of the destruction or deterioration of the wood of dying and dead timber, familiar to all lumbermen, is the injury to fire-killed and storm-felled pine, fir, spruce, etc., caused by boring larvæ known as "sawyers." These borers hatch from eggs deposited by the adult beetles in the bark of the dying trees, and after feeding on the inner bark for a time they enter the solid wood and extend their large burrows deep into the heartwood. Fire-killed white pine is especially liable to this injury, and is often so seriously damaged within three or four months during the warm season as to reduce the value of the timber 30 to 50 per cent. The shortleaf, loblolly, and longleaf pines of the Southern States are damaged to a somewhat less extent, but instances are known in which more than one billion feet of storm-felled timber within limited areas were reduced in value 25 to 35 per cent within three months after the storm. The fire-killed and insect-killed sugar pine, silver pine, and yellow pine of the western forests are also damaged in a similar manner and the value of the product greatly reduced within a few months after the trees die. The aggregate losses from this secondary source in the coniferous forests of the entire country contribute largely to the annual waste of millions of dollars' worth of forest products which otherwise might be utilized.

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[a] Revised extracts from Bulletin No. 58, Part V, Bureau of Entomology, U. S. Department of Agriculture, 1909.

Ambrosia beetles.—Wood-boring insects of another class, known as timber beetles or ambrosia beetles, cause pinhole defects, principally in the sapwood, although some of them extend their burrows into the heartwood. These insects make their attack in the early stage of the declining or dying of the tree, or before the sapwood has materially changed from the normal healthy condition, and often in such numbers as to perforate every square inch of wood. Thus the wood is not only rendered defective on account of the presence of pinholes, but the holes give entrance to a wood-staining fungus which causes a rapid discoloration and produces still further deterioration of the product.

The sapwood of trees dying from the attack of other insects or from fire, storm, or other causes is often reduced in value 50 per cent or more, and in some cases the value of the heartwood is reduced in a like manner from 5 to 10 per cent.

Pinhole borers in cypress.—An example of the destructive work of insects which attack dying and dead trees is found in the cypress in the Gulf States, where these trees are deadened by the lumbermen and left standing several months, or until the timber is sufficiently dry to be floated. Upon investigation it was found that trees deadened at certain seasons of the year were attacked by the ambrosia beetles, or pinhole borers, and that in some cases millions of feet of timber had been reduced 10 to 25 per cent or more in value.[a]

HARDWOOD TREES.

Roundheaded borers, timber worms, and ambrosia beetles.—The principal damage to dying and dead hardwood trees is caused by certain roundheaded wood-borers (Cerambycidæ) with habits similar to the sawyer, by the timber worms mentioned as damaging living timber, and by ambrosia beetles having habits similar to those that attack the sapwood and heartwood of conifers. All of the hardwoods suffer more or less, but the greatest damage is done to the wood of hickory, ash, oak, and chestnut, which are often reduced in value 10 to 25 per cent or more within the period in which it would otherwise remain sound and available for commercial purposes.

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[a] For methods of preventing pinhole injury to girdled cypress see Circular No. 82 of the Bureau of Entomology, U. S. Department of Agriculture.

PREVENTION OF INJURY TO DYING AND DEAD TREES.

A large percentage of the injury to the wood of insect, fire, and lightning killed trees and those killed or dying from injuries by storms, disease, etc., can be prevented as follows:

(1) By the prompt utilization of such timber within a few weeks or months after it is dead or found to be past recovery.

(2) By removing the bark from the merchantable portions of the trunks within a few weeks after the trees are dead (the work to be done either before or after the trees are felled).

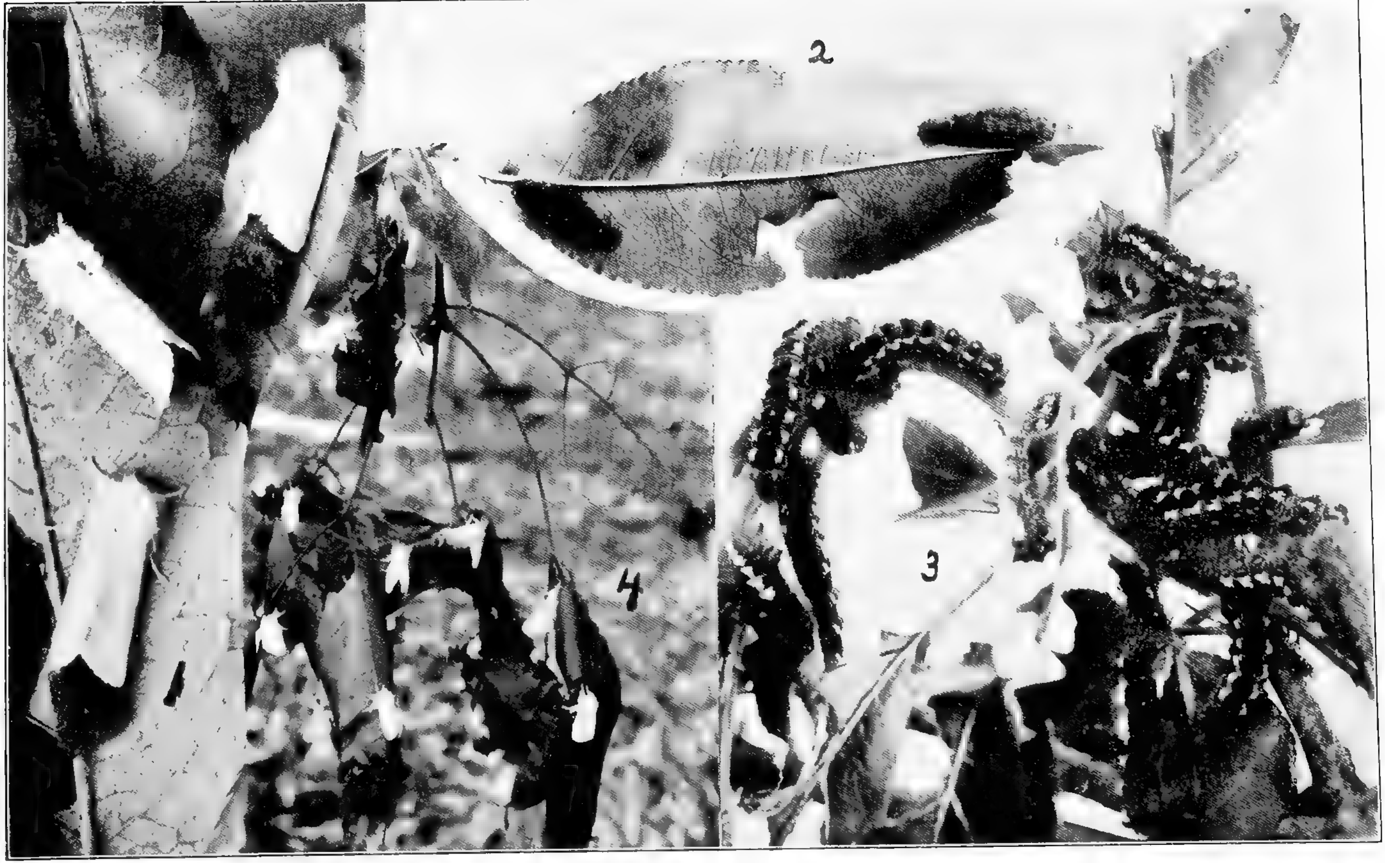
(3) By felling the trees and placing the unbarked logs in water.

(4) By the adoption of a system of forest management which will provide for the prompt utilization of all trees which die from any cause.

Approved:
JAMES WILSON,
Secretary of Agriculture.

WASHINGTON, D. C., *October 7, 1910.*

◆



Various stages of the brown-tail moth.
1. Female moths laying eggs (slightly enlarged). 2. Egg masses. 3. Caterpillars.
4. Cocoons in hickory leaves, with male and female moths emerging (much reduced).

Commonwealth of Massachusetts.

THE GYPSY AND BROWN-TAIL MOTHS.

BULLETIN NO. 2.

ISSUED FROM THE OFFICE OF THE SUPERINTENDENT FOR SUPPRESSING THE GYPSY AND BROWN-TAIL MOTHS.

BOSTON:
WRIGHT & POTTER PRINTING CO., STATE PRINTERS,
18 POST OFFICE SQUARE.
1906.

APPROVED BY

THE STATE BOARD OF PUBLICATION.

Commonwealth of Massachusetts.

OFFICE OF SUPERINTENDENT FOR
SUPPRESSING THE GYPSY AND BROWN-TAIL MOTHS.

The gypsy and brown-tail moths — destructive, introduced foreign insects — by act of the Legislature of Massachusetts have been declared public nuisances and their suppression authorized and required.

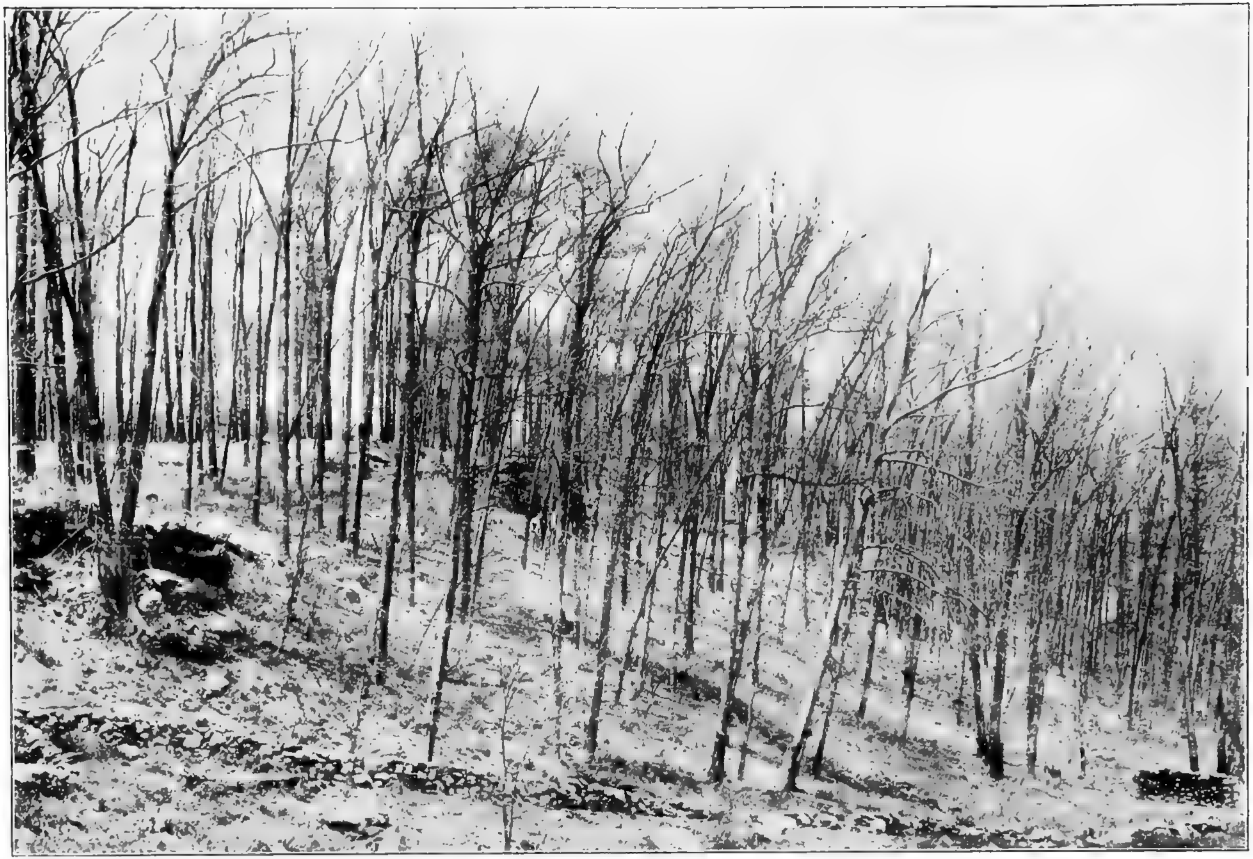
Under chapter 381 of the Acts of 1905, printed in full at the end of this bulletin, certain duties in the suppression of the gypsy and brown-tail moths devolve upon the Commonwealth of Massachusetts, upon its cities and towns and upon its citizens as individuals.

This bulletin is issued by the State Superintendent for Suppressing the Gypsy and Brown-tail Moths for the guidance of cities and towns and of individual citizens in the work of suppression. To this end, certain essential facts concerning the two insects are herewith presented. It is hoped that a perusal of the bulletin will give city and town officials, and individual property owners as well, a clear idea of their rights and duties under the act. It is incumbent on all citizens to familiarize themselves with the appearance and habits of the moths and the means best suited for destroying them. Any insects suspected to be either gypsy or brown-tail moths will be gladly identified at this office, and requests for information or advice will receive prompt attention.

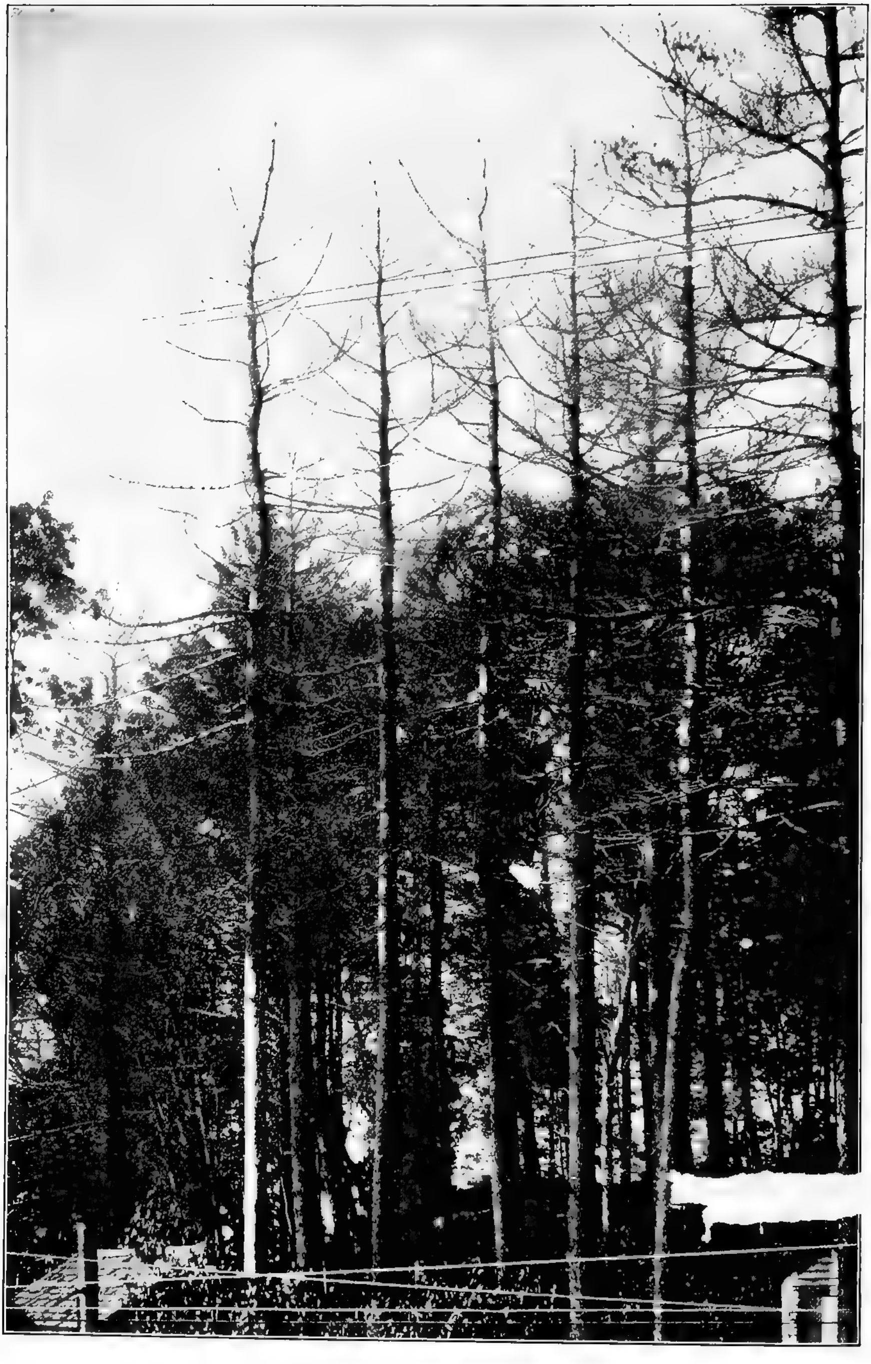
The present bulletin is substantially a reprint of Bulletin No. 1, issued Sept. 1, 1905, of which an edition of 25,000 copies has become exhausted. A number of new illustrations are included. The amended law is printed in full and certain additions to the text have been made which it is hoped will make the pamphlet more generally useful to those engaged in protecting their trees from injury by the moth pests.

A. H. KIRKLAND,
Superintendent.

6 BEACON STREET, BOSTON, MASS.,
Aug. 15, 1906.



Menotomy Rocks Park, Arlington, devastated by gypsy moth caterpillars, June, 1905.



Pines, Lebanon Street, Malden, stripped by gypsy moth caterpillars in 1904; dead in 1905.

THE GYPSY AND BROWN-TAIL MOTHS.

THE GYPSY MOTH.

As far back as authentic records exist, the gypsy moth has been a destructive insect pest in Europe; at times increasing enormously and disastrously, then for other periods decreasing, only to increase again and renew its extensive ravages. At the present time it is most numerous and destructive in southern Russia.

Up to the year 1868 the gypsy moth was not known to exist anywhere within the western hemisphere. In that year the insect was brought from Europe by an experimenter to Medford, Mass. Soon escaping, it spread into many cities and towns of eastern Massachusetts, and, increasing enormously, became in 1890 so serious a pest that the Commonwealth began exterminative work against it. This was continued for ten years. By 1900 the State work had so reduced the moth that it was doing little or no serious damage, and had, indeed, ceased to be generally noticed, having been exterminated in many places. The Commonwealth then abandoned its operations against the insect; whereupon it rapidly gained headway, and soon became again a formidable menace. To-day, in many localities, the gypsy moth occurs in enormous numbers, as it did in 1890, but it is found over a much larger territory than it occupied at that time.

The Damage caused by the Gypsy Moth.

The gypsy moth caterpillar will attack all fruit, shade and woodland trees. It shows a preference for the apple, white oak, red oak, willow and elm. It will devour on occasion nearly every useful grass, plant, flower, shrub, vine, bush, garden or field crop that grows in Massachusetts.

The caterpillar kills both deciduous and coniferous trees. Woodlands assailed by it in formidable numbers are stripped bare, as in winter, and many trees are killed. While several consecutive strippings are usually necessary to cause the death of a healthy deciduous tree, one thorough stripping will kill the white pine and other coniferous trees. Where the gypsy moth abounds in residential districts, it not only eats nearly everything green, but it swarms, in caterpillar form, upon houses, walks and verandas and often enters dwellings. In residential districts most heavily infested by the moth real estate tends to rapid depreciation, so that it sometimes becomes a matter of difficulty to rent or sell property.

Life History.

The gypsy moth, like all insects of its class, exists under four different forms during the year.

The Egg. — The eggs of the gypsy moth are laid in July and August in a yellowish, hair-covered mass averaging about one and one-half inches long and about three-fourths of an inch wide. To the eye the egg mass resembles a small, tightly stuffed, oval, buff-colored cushion. During winter the color often fades to a dingy white. In this mass, the eggs, to the average number of about five hundred, are closely packed with yellowish hair from the body of the female moth. An individual egg is scarcely as large as a pinhead, salmon-colored when first laid, but turning dark in the course of a few weeks.

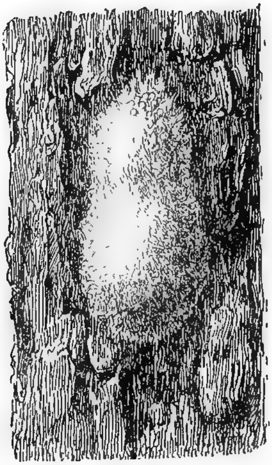


FIG. 1.—Egg cluster of gypsy moth.

The Caterpillar or Larva. — The eggs hatch about May 1, and each mass or "cluster" yields a swarm of small caterpillars, the bulk of which become fully grown by midsummer. Gypsy moth caterpillars of any age are decidedly hairy. The head of the caterpillar is large in proportion to its body, this being especially noticeable when it is young.

The mature caterpillar has a dusky or sooty-colored body. Along the back, counting from the head, which is marked with yellow, is a double row of blue spots followed by a double row of red spots. This double row of spots almost invariably may be seen very distinctly on the back of a gypsy moth caterpillar which has attained a length of one inch and a half or more. There are five pairs of blue spots and six pairs of red spots. No other New England larva has this double row of blue and red spots along its back. Until the gypsy moth caterpillar grows to the length of an inch and a half, however, it does not always show very distinctly these pairs of spots. The mature gypsy moth caterpillar not infrequently attains a length of three inches.

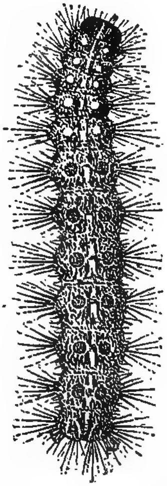
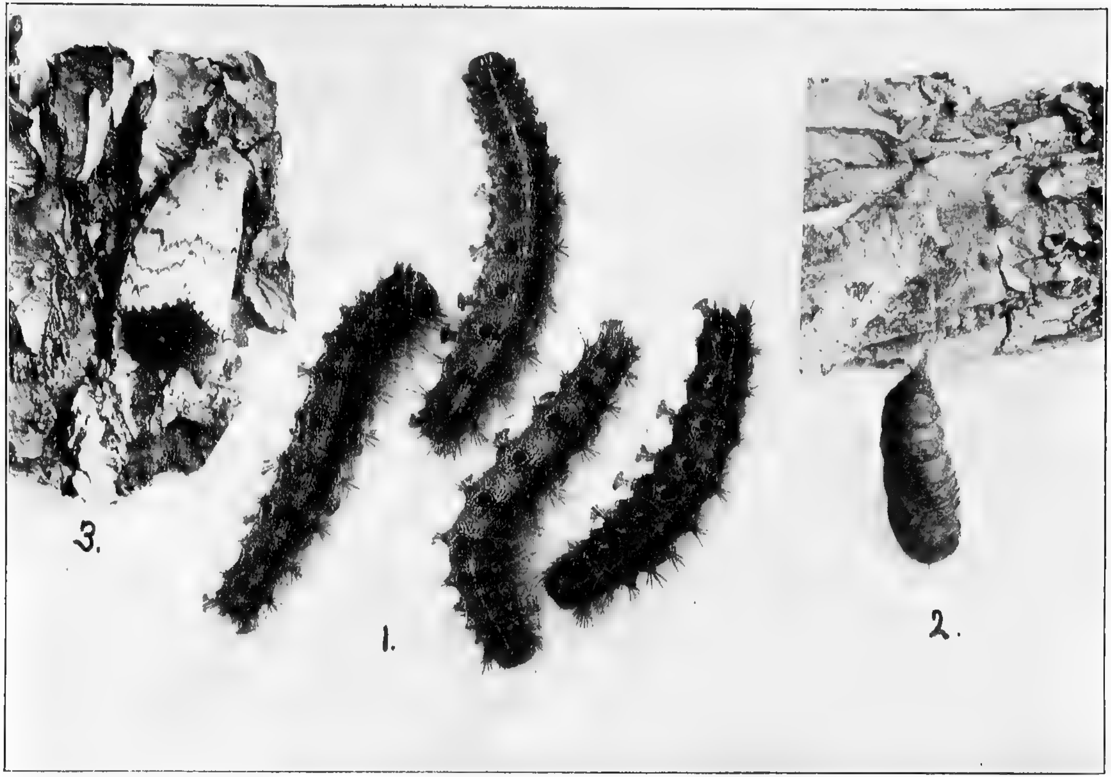
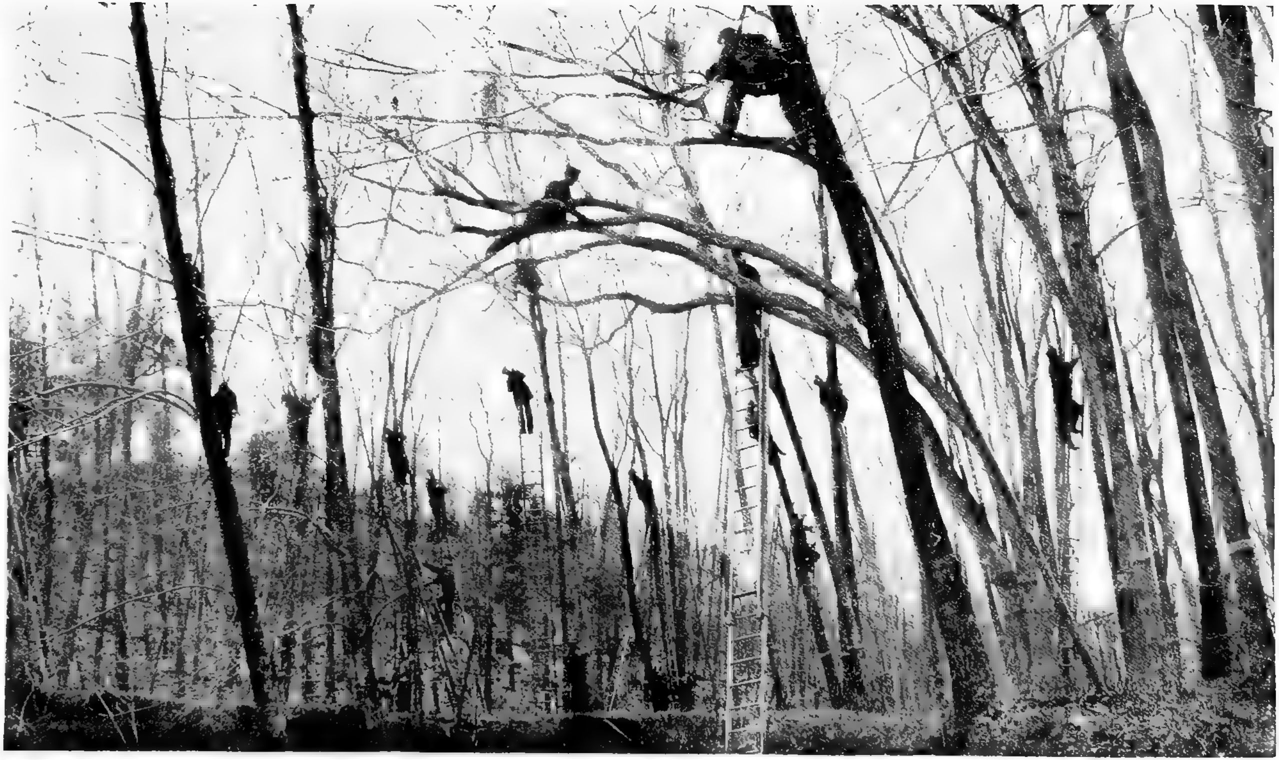


FIG. 2.—Full-grown caterpillar of the gypsy moth.



Various stages of the gypsy moth.
1. Full-grown caterpillars. 2. Pupa. 3. Female moth laying egg cluster.
All figures life size.



Work of killing the eggs of the gypsy moth in woodland.
Massachusetts Board of Agriculture Report, 1898.

The Pupa. — When fully grown, usually in July, the caterpillar spins a few threads of silk as a supporting framework, casts its skin and changes into a pupa, or, as it is sometimes called, a chrysalis. The pupa is dark reddish or chocolate in color and very thinly sprinkled with light reddish hairs. Unfortunately it resembles the pupæ of certain other moths found in Massachusetts, and cannot, unless by experts, be identified at a glance. The thinly sprinkled, light reddish hairs are, however, characteristic.

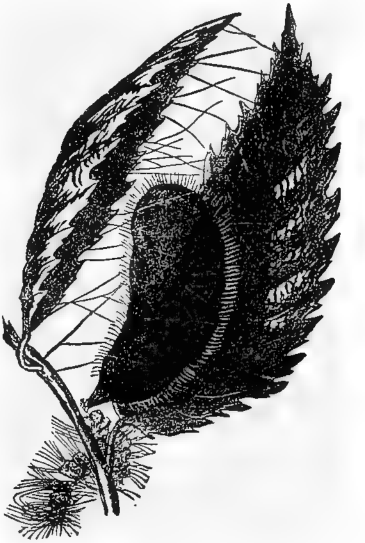


FIG. 3. — Pupa of gypsy moth.

The Moth. — From July 15 to August 15 the winged moths emerge from the pupæ, the date varying according to the season and time of pupation. The male moth is brownish-yellow, varying to greenish-brown in color, has a slender body and expands about one and one-half inches. It flies actively by day, with a peculiar zigzag flight.

The female moth is nearly white, with numerous small black markings, heavy bodied and sluggish, and expands about two inches. The female does not fly, otherwise the spread of the gypsy moth would be most rapid. After mating, the moths live but a short time. The female dies after depositing her egg mass. The winged moths take no food. All damage to foliage is caused by the caterpillars.

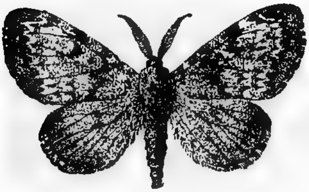


FIG. 4. — Male gypsy moth.

Distribution.

The gypsy moth spreads chiefly during the caterpillar stage. While the caterpillars do not crawl very far from where they hatch, except when there is a scarcity of food, they have the habit, when small and young, of spinning down on their silken threads from trees, and, falling on vehicles, are then carried from place to place. Electric cars, pleasure and business vehicles, bicycles and automobiles are common means of thus transporting the gypsy moth. The special attention of all those upon whom gypsy moth suppression devolves is therefore directed to the necessity of keeping the neighborhoods of travelled highways free from the insect. The caterpillars often crawl upon vehicles standing in an infested spot, and by this means also are carried from one place to another. The egg clusters of the gypsy moths may also be transported upon any of the numerous objects on which they are laid. Freight cars that have stood near infested foliage for a period long enough for the laying of gypsy moth eggs upon them may even thus transport the pest. The gypsy moth is now found in the following cities and towns: —

List of Cities and Towns infested by the Gypsy Moth.

Abington.
Acton.
Amesbury.
Andover.
* Arlington.
Ashland.
Avon.
Ayer.
Barnstable.
Bedford.
* Belmont.
* Beverly.
Billerica.
* Boston.
Bourne.
Boxford.
Braintree.
Bridgewater.
Brockton.
* Brookline.
* Burlington.
* Cambridge.
Canton.
Carlisle.
Carver.
Chelmsford.
* Chelsea.
Cohasset.
Concord.
* Danvers.
Dedham.
Dover.
Dracut.
Duxbury.
East Bridgewater.
* Essex.
* Everett.
Framingham.
Georgetown.
* Gloucester.
Groveland.
Halifax.
Hamilton.
Hanover.
Hanson.
Haverhill.
Hingham.
Holbrook.
Holliston.
Hopkinton.
Hudson.
Hull.
Hyde Park.
Ipswich.
Kingston.
Lakeville.
Lawrence.
* Lexington.
Lincoln.
Lowell.
* Lynn.
* Lynnfield.
* Malden.
* Manchester.
* Marblehead.
Marlborough.
Marshfield.
Maynard.
* Medford.
* Melrose.
Merrimac.
Methuen.
Middleborough.
Middleton.
Millis.
Milton.
* Nahant.
Natick.
Needham.
Newbury.
Newburyport.
* Newton.
North Andover.
North Reading.
Norwell.
Norwood.
Orleans.
* Peabody.
Pembroke.
Plymouth.
Plympton.
* Quincy.
Randolph.
* Reading.
* Revere.
Rockland.
Rockport.
Rowley.
* Salem.
Salisbury.
* Saugus.
Scituate.
Sherborn.
* Somerville.
Southborough.
* Stoneham.
Stoughton.
Stow.
Sudbury.
* Swampscott.
Tewksbury.
Topsfield.
* Wakefield.
* Waltham.
Wareham.
* Watertown.
Wayland.
Wellesley.
Wenham.
West Bridgewater.
Westborough.
Westford.
West Newbury.
Weston.
Westwood.
Weymouth.
Whitman.
Wilmington.
* Winchester.
* Winthrop.
* Woburn.
Yarmouth.

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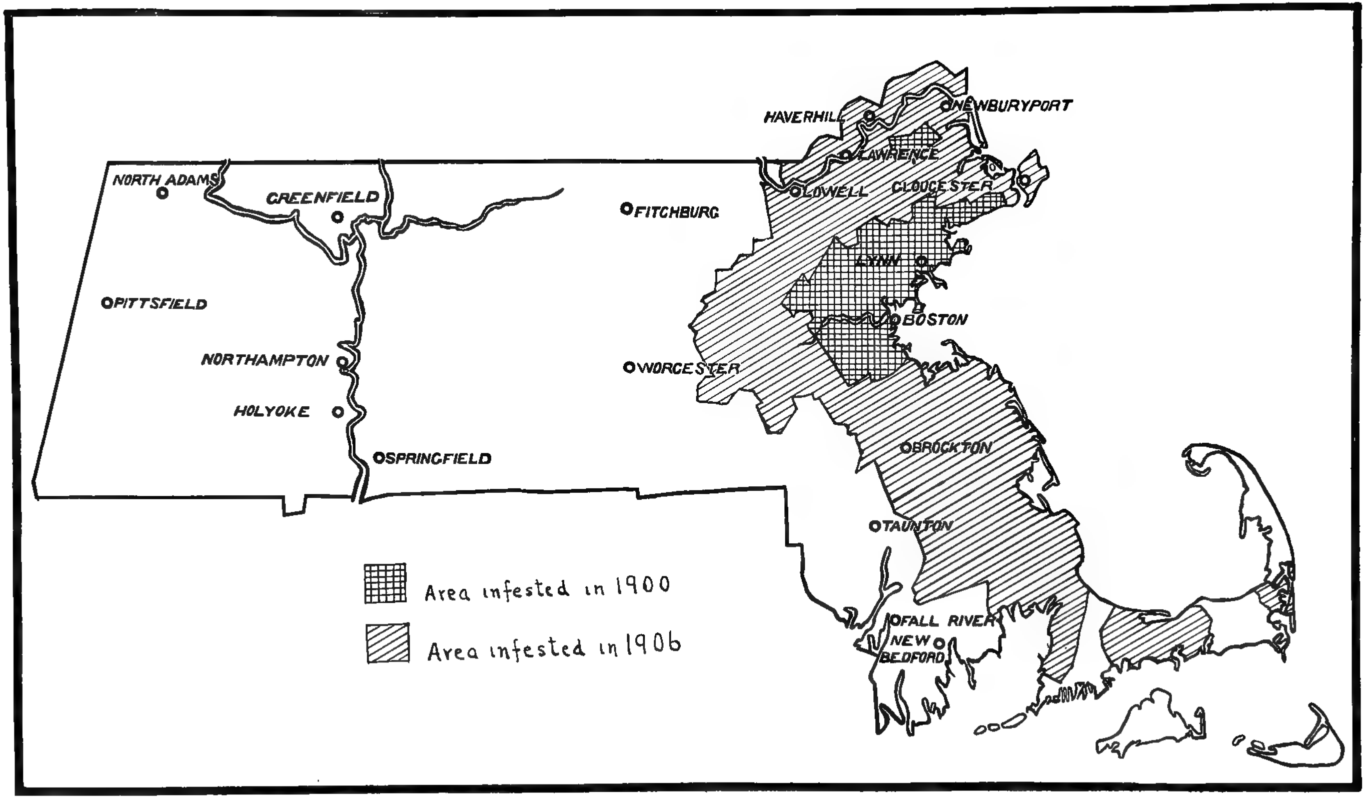
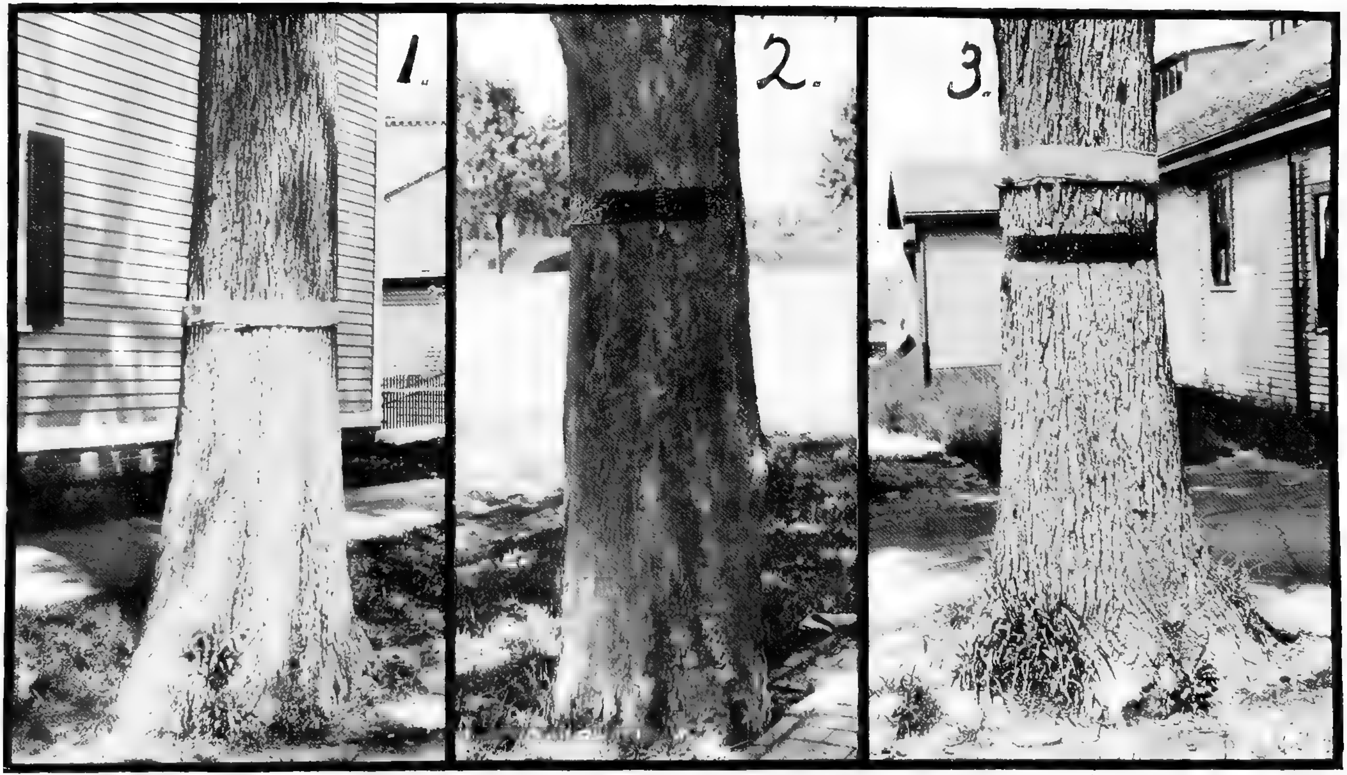
* Indicates the cities and towns which constitute the heavily infested central district.



Gypsy moth infested district in Massachusetts: 1900, 359 square miles; 1906, 2,287 square miles.



Methods of banding trees infested with the gypsy moth.

1. Burlap. 2. Sticky band. 3. Combination of burlap and sticky band.

There can be little doubt that the gypsy moth occurs over a considerably larger area than the foregoing. Owing to the existence of large colonies of the moth on main lines of travel in eastern Massachusetts, it seems probable that the insect will be found ultimately at least throughout the eastern part of the State. Outside the State it now occurs in southeastern New Hampshire, Providence, R. I., and Stonington, Ct.

Where to look for the Gypsy Moth.

The Egg. — From August to May the egg masses of the gypsy moth may be found in places near which the moth emerged from the pupa case. In laying, the female moth chooses tree trunks, the under sides of limbs, sheltered crotches and holes in trees, hollow trees, crevices in or under rough bark, etc. The egg clusters are also found on shrubbery, buildings, scattered and heaped rubbish, barrels, boxes and similar objects standing out of doors, wood piles, stone piles, fences, walls, boulders and the like. Gypsy moth egg clusters have been found upon an immense variety of objects, and occasionally may be seen in almost any situation that is not too far from vegetation. The tendency is to deposit the eggs on the lower or inner surface of an object. The moths disregard all rules when they swarm in a place, and their egg clusters may then be found plentifully in sight as well as out, and in all sorts of places, even within buildings.

The Caterpillar. — From May to August the caterpillars may be found in various stages of growth, diminishing in numbers rapidly after July 15. In the spring the small caterpillars should be looked for on the foliage, feeding principally on the under side of the leaf. As the caterpillars grow, they molt or cast their skin several times, and these molted skins are characteristic signs of the presence of the moth. As the caterpillars acquire size, they commence to feed by night, and during the day seek shelter, generally in clusters, on the shady side of tree trunks, beneath large limbs, under rough or loose bark, in holes in trees, under fence rails, in walls, stone heaps, rubbish piles, in short in any accessible place offering shelter from the sun and the birds.

The Pupa. — Gypsy moth pupæ are most abundant during the latter half of July. They are to be found in the same situations as are chosen for depositing the egg clusters, and not infrequently, also, in the foliage of trees and shrubs.

The Moth. — The peculiar zigzag flight of the male moth has already been noted. The large, white, conspicuous female moths sit or crawl on tree trunks, etc., near their pupa cases. In July (chiefly the latter half) and through August these females may be found busily engaged in laying their eggs.

Danger Signs. — The bristly, cast-off molt skins of the gypsy moth caterpillars, often with the head cases attached, may frequently be found in the situations chosen for the eggs and pupæ. They are often massed in bunches, and are very commonly associated with empty gypsy moth pupa cases or hatched or unhatched gypsy moth egg clusters.

Gypsy moth molt skins and empty pupa cases are resistant to weather and decay, and may be found at any season of the year. The presence in any locality of such molt skin, empty pupa case or hatched egg cluster of the gypsy moth indicates the probable presence near by of the living moth in some form, and therefore is a sign of danger not to be disregarded. The hatched-out egg masses of a previous year often remain intact in sheltered places, and thus give a clue to the presence of the insect.

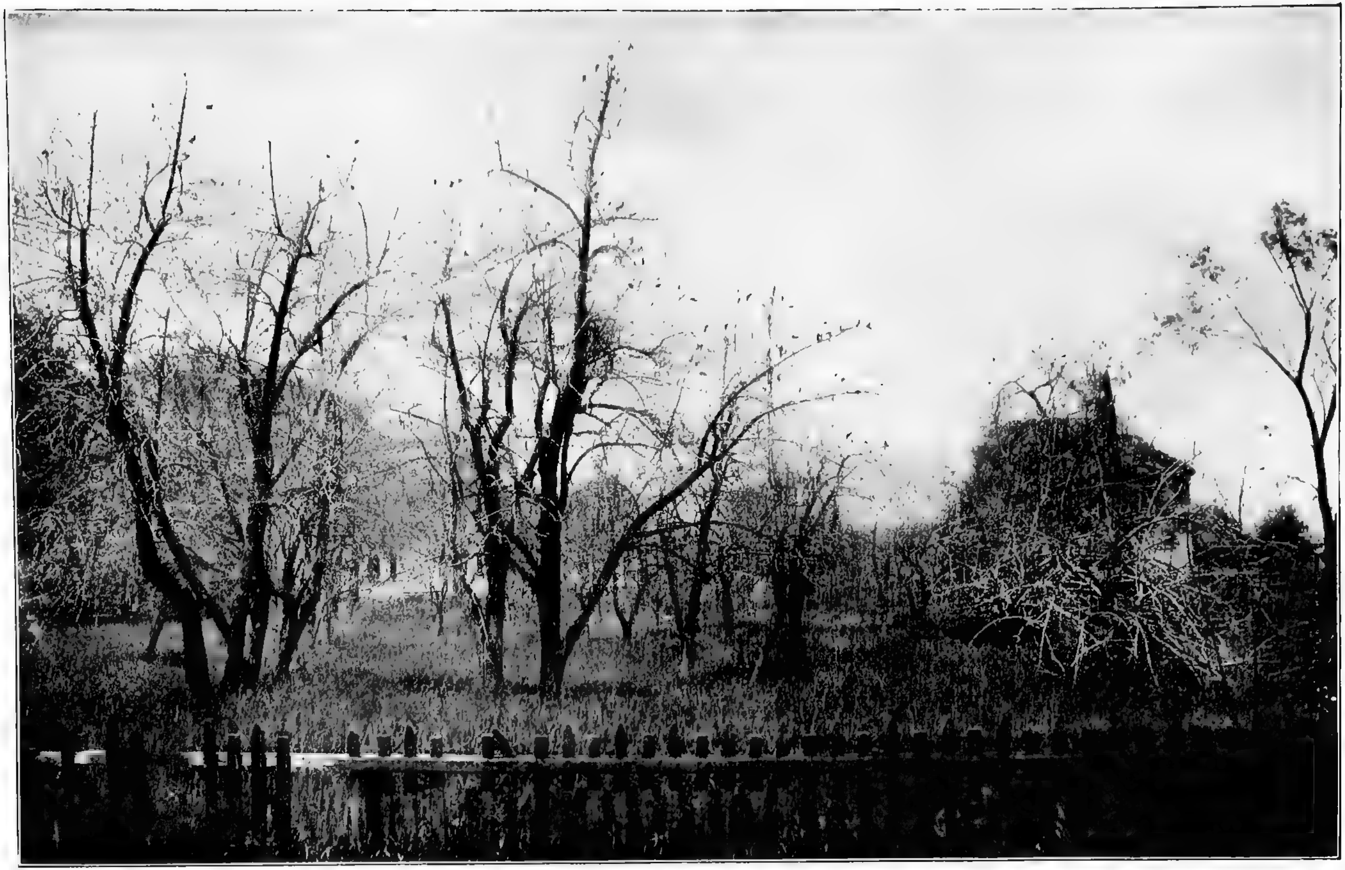
THE BROWN-TAIL MOTH.

This insect, like the gypsy moth, a common European pest of fruit and shade trees, has been an object of interest to gardeners from the earliest times. Throughout Europe it is known as the "common caterpillar," and accounts of its habits and periodical ravages are to be found in nearly all European works on entomology and horticulture. It found its way accidentally to Somerville, Mass., in the early nineties, probably in a shipment of roses from Holland, multiplied, spread, and is now generally disseminated over eastern New England.

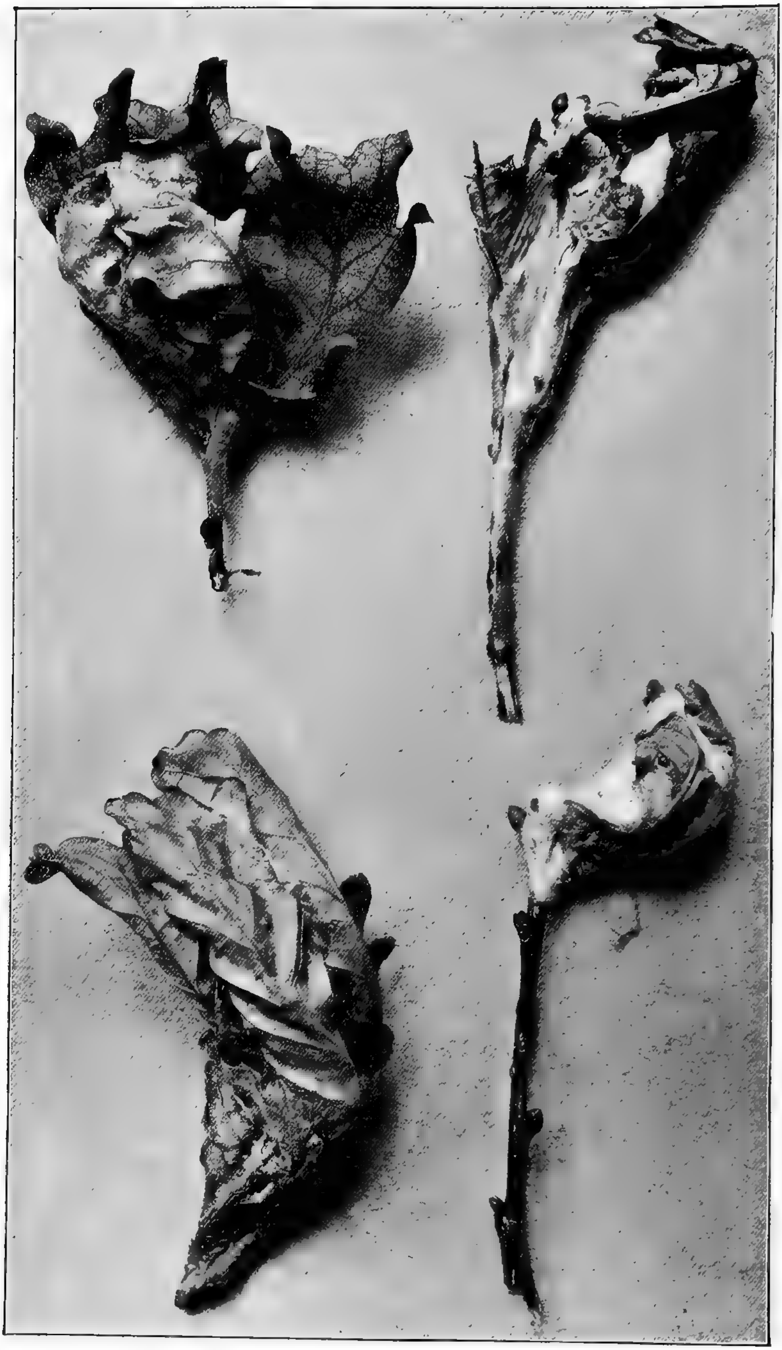
Damage by the Brown-tail Moth.

While at first a pest of the pear and other fruit trees, the brown-tail moth has now adapted itself to feeding on various species of forest trees, notably the oaks. In the spring, as soon as the buds unfold, the young caterpillars begin to feed, and where numerous completely strip even large trees. When the food supply gives out, they swarm forth along fences, walks, etc., in search of foliage.

The damage by the caterpillars to the fruit trees is only a part of the harm wrought by them. Whenever these insects come in contact with human flesh, they produce a most severe and painful nettling. This is due apparently not to any poisonous material in the hairs, but rather to the finely barbed and brittle hairs themselves. So severe is this affection that in many cases people have



Ravages of brown-tail moth caterpillars in neglected pear orchard. Winchester, June, 1905.



Winter webs of brown-tail moth on English oak.

Photo loaned by Chas. Bradley, Superintendent of Farm School, Thompson's Island.

Massachusetts Board of Agriculture, Special Report on Brown-tail Moth, 1903.

been made seriously ill by it. The best remedy for it is the liberal use of cooling lotions, or what is more satisfactory, even if less pleasant, the free use of common vaseline.

Where the brown-tail moth caterpillar exists in great numbers, it at times gathers upon houses and even enters them, causing extreme annoyance. Like the gypsy moth, the brown-tail moth, where it abounds, depreciates the value of residential property.

Life History.

The Egg. — The egg mass of the brown-tail moth somewhat resembles that of the gypsy moth, but it is laid on the under side of a leaf — seldom on a tree trunk — and is smaller and more elongated and of a brighter reddish-brown color. From July 15 to the end of the month, the white moths lay their eggs in brown, hair-covered masses on the leaves near the top of pear and other trees. Each egg cluster contains about three hundred eggs, closely packed in a mass about two-thirds of an inch long by one-fourth of an inch wide.

The Caterpillar. — The eggs hatch during August, and the young caterpillars begin to feed in clusters on the upper surface of the leaves. They soon commence the work of spinning their winter webs. In making the web a number of leaves in the vicinity of the egg clusters are drawn together and carefully spun in with a tenacious silken web. The web is grayish in color, composed of dead leaves and silk, and is very hard to tear apart. Each web contains about two hundred and fifty caterpillars, and varies in length from four to six inches. With the approach of cold weather the caterpillars enter the web and close the exit holes. We then have the strange phenomenon of a caterpillar wintering over when only one-quarter grown, and emerging the following spring to complete its life history. The extremes of cold in Massachusetts do not seem to affect these insects adversely. They emerge in the spring, usually early in April, eat first the buds and then the blossoms, and attack the foliage of fruit trees as soon as it develops. The full-grown caterpillar is about two inches in length, with a broken white stripe on either side and two conspicuous red dots on the back near the posterior end.

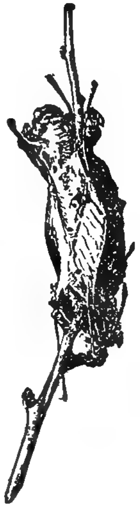


FIG. 5. — Winter web of brown-tail moth (reduced).

Stripping the foliage of one tree, they go to others, and continue to eat until full grown, when the cocoons are spun within the leaves at the ends of the branches or sometimes on the tree trunks.

The Pupa. — The caterpillars pupate within their cocoons at the tips of twigs. Usually the mass of cocoons is formed within a spray of leaves, but at times the cocoon is made on a house wall, fence, tree trunk, etc. The pupa is a compact, dark-brown body, about five-eighths of an inch long, with yellowish-brown hairs scattered over its surface. Pupation takes place the latter part of June, and the moths emerge about the middle of July.

The Moth. — The moths are pure white on the wings. The male is slender bodied, while the female has a conspicuous bunch of brown hair at the tip of the abdomen, hence the name "brown-tail moth." The female has a wing expanse of about one and one-half inches, the male being slightly smaller.

Both the male and female brown-tail moths fly mainly by night, and are greatly attracted to lights. As in the case of the gypsy moth, all the destructive work of the brown-tail moth is done by its caterpillar, which, unlike the gypsy moth caterpillar, habitually feeds by day.

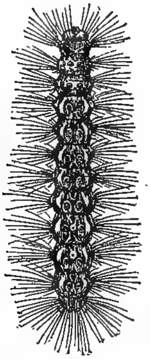


FIG. 6. — Full-grown caterpillar of the brown-tail moth.

Distribution.

The brown-tail moth is known to have spread at least as far to the northeast as Eastport, Me., and as far south as Cape Cod, Mass. To the west it has been found at Amherst, Mass. The eastern portion of Massachusetts from north to south is now quite solidly infested, though less so south of Boston, and the moth doubtless exists in many communities in and out of Massachusetts from which it has not yet been reported.

The female winged brown-tail moth, like the male, is a strong, swift flyer and can carry her eggs long distances before depositing them. For this reason the brown-tail moth has spread much farther from its point of introduction in Massachusetts than has the gypsy moth. In its flight the brown-tail moth is often aided by strong winds. It is also transported on steamboats and in electric and steam cars to which it is attracted at night by the lights.

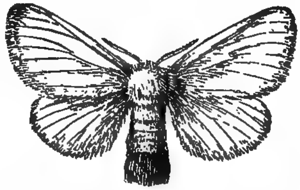
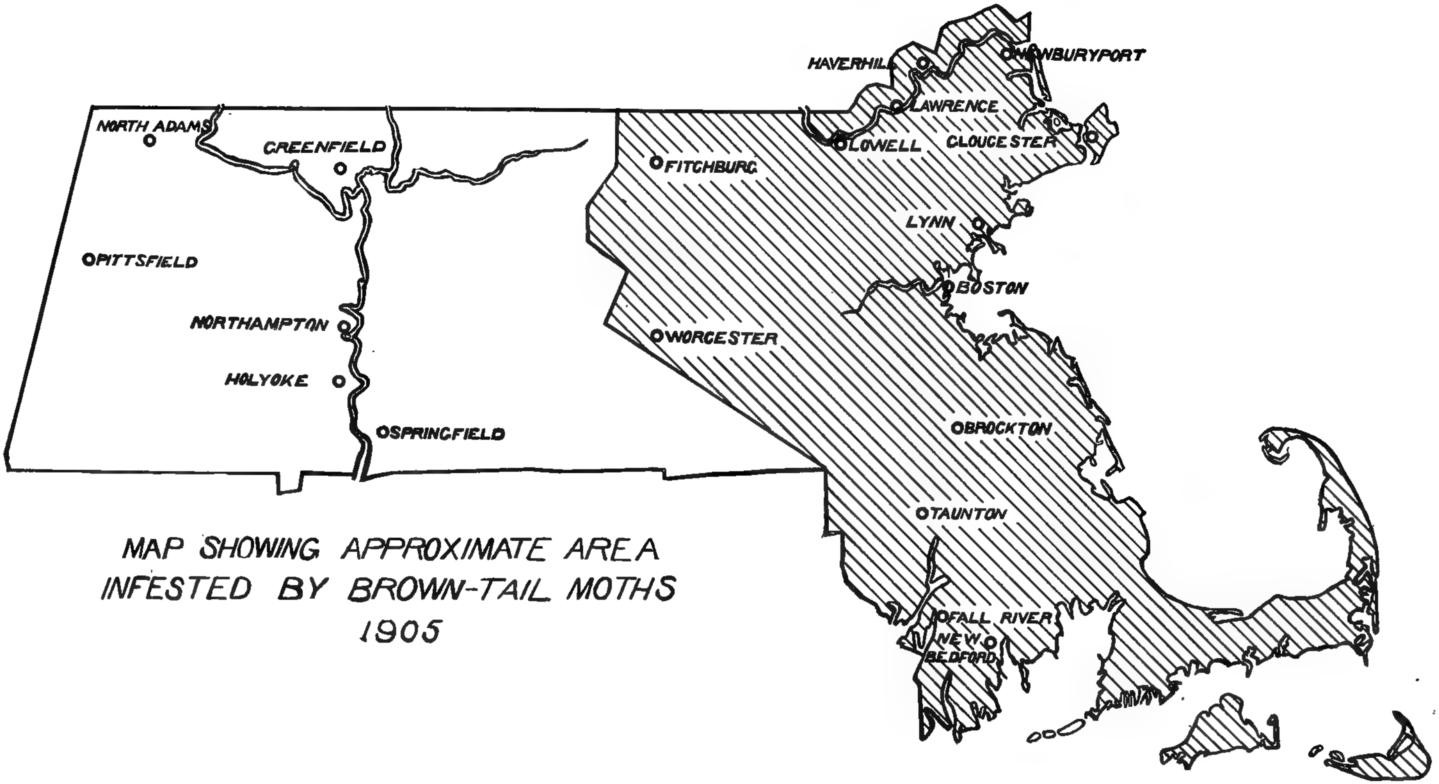


FIG. 7. — Female brown-tail moth.

The caterpillar of the brown-tail moth has, when young, the "spinning down" habit already described in the case of the gypsy



MAP SHOWING APPROXIMATE AREA
INFESTED BY BROWN-TAIL MOTHS
1905

moth caterpillar, and is similarly transported by vehicles and pedestrians. The neighborhoods of travelled highways, therefore, should be kept free from the brown-tail as well as from the gypsy moth.

THE SPECIES CONTRASTED.

The gypsy moth and the brown-tail moth are constantly confused in the minds of many people. The following marked differences between the two should be noted: —

a. The egg cluster of the gypsy moth is rarely found on the under side of a leaf, and is commonly a rather robust-looking object, often two inches long and relatively thick and broad.

The egg cluster of the brown-tail moth is almost always deposited on the under side of a leaf, and is smaller and more slender than a typical gypsy moth egg cluster.

b. The gypsy moth caterpillar, when well grown, has a dark grayish or sooty-colored body, marked conspicuously along the back, counting from the head, with a double row of blue spots followed by a double row of red spots.

The brown-tail moth caterpillar, when well grown, is of a bright tawny or orange-brown color, marked along each side of the body by a conspicuous row of pure white spots, and having two bright red spots at the lower end of the back.

c. The female gypsy moth has a wing spread of about two and one quarter inches, and her general color is a dingy white lightly streaked and blotched with blackish and faint grayish. Her abdomen has no thick, conspicuous patch of golden or brownish hairs at the tip. Though she has large wings (which she often flutters), she does not fly, but merely crawls short distances.

The female winged brown-tail moth is much smaller than the female gypsy moth, with much less spread of wing. Her color is a remarkably pure, unsullied, snow white. At the tip of her abdomen is a very conspicuous, unmistakable, sharply contrasted, thick, rounded patch of golden or brownish hairs.

The female brown-tail moth is a swift, strong flyer, mainly flying by night, and is greatly attracted to lights.

d. The gypsy moth caterpillar never weaves a nest or web in which to hibernate during cold weather. The gypsy moth winters in the egg form, never as a caterpillar.

The caterpillar of the brown-tail moth always weaves a hibernating nest or web in which to rest torpid during the winter. Throughout cold weather the brown-tail moth is in caterpillar form, dormant and snugly ensconced inside its nest, which is placed at or near the tip of a twig. With the warm weather of spring the brown-tail moth caterpillar does not "hatch", but simply awakens to animation, crawls out of the nest and begins to feed.

e. The gypsy moth does not, in any of its forms, produce noteworthy irritation of the human skin.

The brown-tail moth caterpillars and cocoons, by reason of their hairs, cause a most annoying and painful irritation. The female brown-tail moths, in their struggles to emerge from the cocoons, often acquire a certain number of caterpillar hairs, and hence are sometimes, though rarely, the cause of the irritation above mentioned.

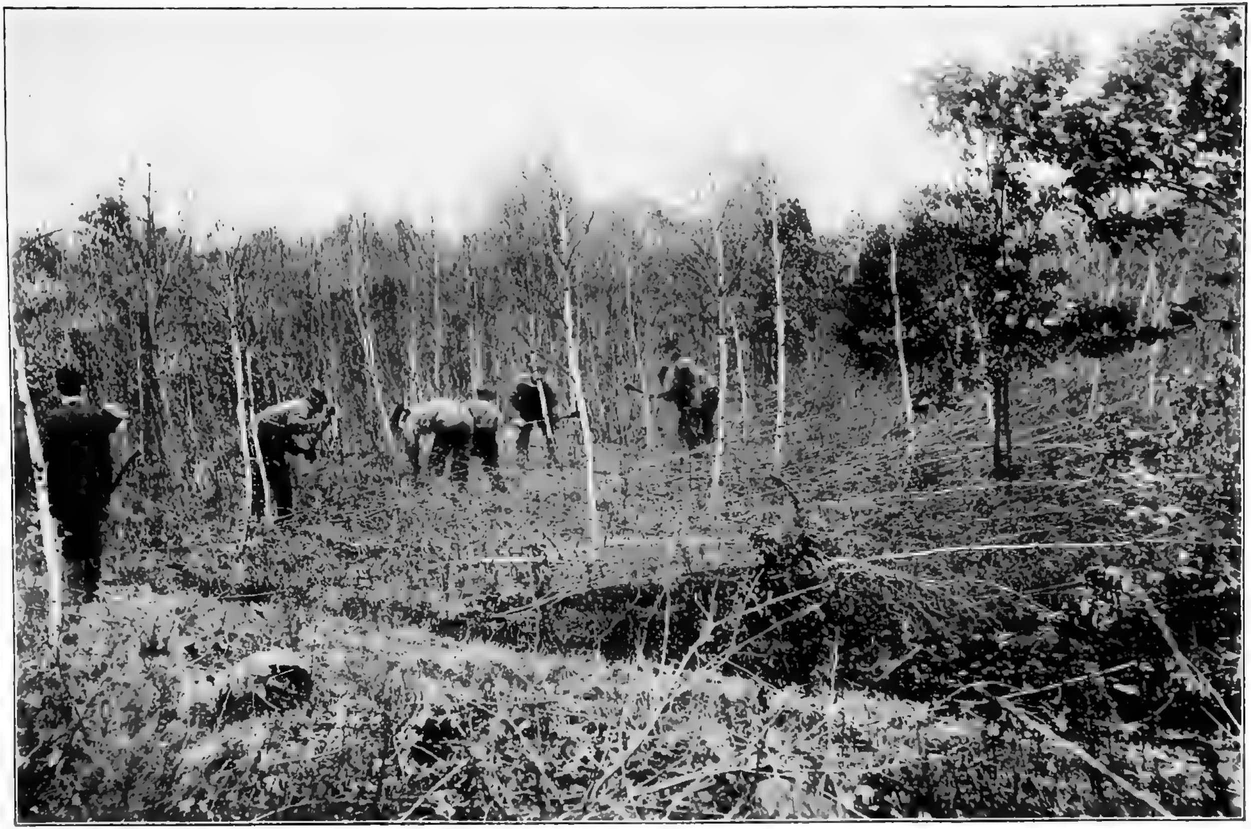
REMEDIES AGAINST THE MOTHS.

The Gypsy Moth.

Egg killing. — No single method of destruction against the gypsy moth is more effective than killing the eggs. The egg masses wherever accessible can be killed from August to May by soaking them thoroughly with creosote mixture. The creosote may be applied with a small swab or paint brush. In killing gypsy moth eggs in high trees, it is usually best to work with two men; one man to point out the egg clusters from the ground, another to kill the eggs in the trees. Creosote mixture may be purchased at agricultural warehouses and seed stores at from fifty cents to one dollar per gallon, depending on quantity.

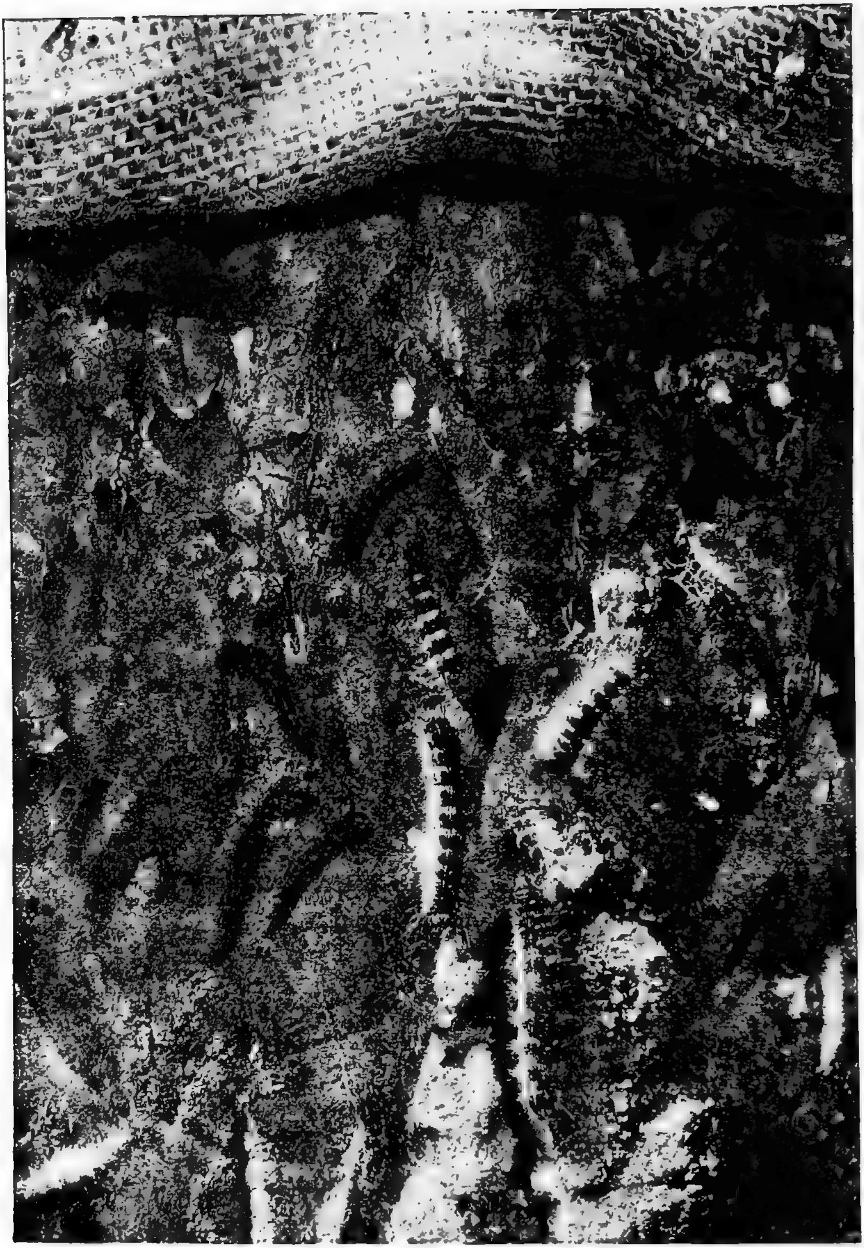
Where trees and shrubbery (especially low-cost woodland and unimproved tracts of brush) are extensively infested with the eggs of the gypsy moth, the growth should be cut and burned. The eggs are, however, remarkably resistant to fire, and an intense heat applied directly to the clusters is required to kill them all. Where the clusters are very plentiful, burning the ground over with oil to destroy eggs scattered as a result of the cutting of trees and bushes will be required to insure thorough work.

Caterpillar Destruction.— Spraying infested foliage with arsenate of lead at the rate of ten pounds to one hundred gallons of water is very effective when the caterpillars are small. Any of the common hand outfits will suffice for the spraying of shrubs or flowering plants. For use on trees, a pump mounted on a barrel or hogshead is desirable. The poison should be thoroughly mixed in water, and applied, if possible, on a clear, dry day, in such a manner as to cover the leaves, rather slowly, with a fine mist. The foliage should never be drenched with a stream. When the leaves begin to drip, spraying should at once cease. Spraying should begin at the top of the trees. This work is most effective when done during May and early June. Where tall street trees or trees in



Work of removing thick growth from infested sproutland, leaving trees for burlaps.

Massachusetts Board of Agriculture Report, 1899.



Section of burlap band raised, showing gypsy moth caterpillars that had gathered beneath it on the trunk of an elm tree.

Massachusetts Board of Agriculture Report, 1895.

easily accessible woodland are to be sprayed, the use of a power outfit is to be recommended. Steam or gasoline engine sprayers are not so economical of the spray as hand pumps, but make a great saving in the cost of labor. Furthermore, with a properly equipped power outfit the work can be done with the greatest possible rapidity. Where arsenate of lead cannot be obtained, Paris green, one pound to one hundred and fifty gallons of water, may be used, but it should be borne in mind that this insecticide often scorches the foliage, and that it washes off with the first rain. Arsenate of lead is not open to these objections.

Burning over infested wood or brush land in May or June is a very effective method of destroying gypsy moth caterpillars, and is the logical complement to the method of egg killing by burning previously described. The trees and bushes should be cut before the hatching time of the eggs, and may be left lying as they fall. A few trees should be left standing, and to these such caterpillars as escape the burning will resort for food, and they may then be killed by spraying or by burlapping, as described farther on. The burning of the fallen trees and brush should be done when the caterpillars are very young and small. At this time they quickly succumb to flame. When the caterpillars are older, burning is less effective.

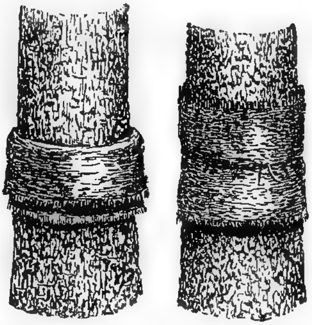


FIG. 8.—Manner of applying the burlap.

If a strip of burlap or other coarse, cheap cloth is tied about an infested tree trunk by the middle, in such manner that the flaps hang down, the caterpillars, as soon as they have acquired the night-feeding habit, will gather under the cloth and can then be destroyed by crushing or by cutting with a sheath knife. The burlaps should be examined daily, or, when the caterpillars are in great numbers in a locality, several times a day. Burlap can be successfully employed from the latter half of May to the first or middle of August, for the caterpillars commonly pupate under burlap and winged moths lay many eggs under it. It should be borne in mind that the cloth band is in no sense a tree protector; nor is it a trap. Its function is simply to give the shelter which the caterpillars seek by day. Serving as it does as a hiding place for various insects, it is better off the tree than on unless it can be attended to and kept clean. At the end of the caterpillar season, all burlaps should be removed and burned. To insure best results on high trees, such as street elms, burlaps should be placed around some of the larger limbs, as well as around the trunk, as many caterpillars will seek shelter up in the tree rather than descend to the ground. The most effective results in using the burlap are obtained where cavities, crevices, etc., in the trees have been first filled with cement or covered with zinc and all loose bark removed. If these hiding places are destroyed, nearly all the caterpillars will seek the burlap at some time during the season.

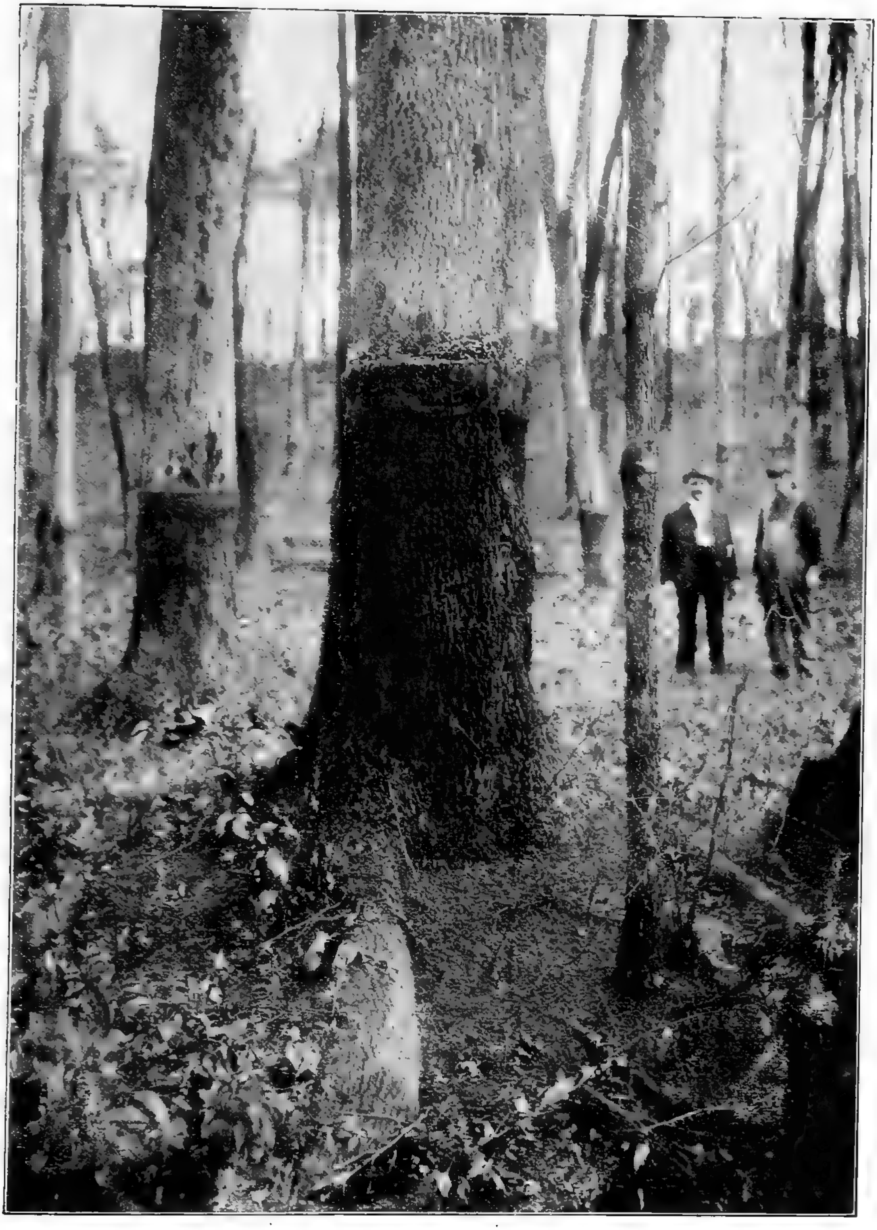
Banding a non-infested tree with insect lime or other sticky substance or mixture to keep the caterpillars out of it is an effective means of protection, provided the branches of the tree do not interlock with those of an infested tree, and provided the two do not stand so near that the small caterpillars can pass from the infested tree to the other by means of their fine threads. A band, of whatever material composed, to be effective must remain sticky. When caterpillars are numerous in a place, they often, in their attempts to cross the band, bridge it over with their threads and dead bodies, with the result that other caterpillars coming later are able to ascend the tree. For this reason and in order that the caterpillars which collect beneath may be killed, the sticky band should be frequently inspected. If the many caterpillars which frequently "herd" below the sticky bands are not killed, they will in time leave the trees for shrubbery, where they are less easily destroyed, there to complete their feeding period and transform into moths. Insect lime, raupenleim, tanglefoot, bodlime, printer's ink or even axle grease are among the materials most used for banding. All may be dangerous to the tree and should be removed after the caterpillar season has passed.

Destroying Pupæ and Moths. — Pupæ are commonly found under the burlap and in other places frequented by the caterpillars. They are often massed under large branches or in other sheltered places. In similar locations the female moths may be found in numbers. Both forms of the insect may be crushed by hand to advantage during July and August.

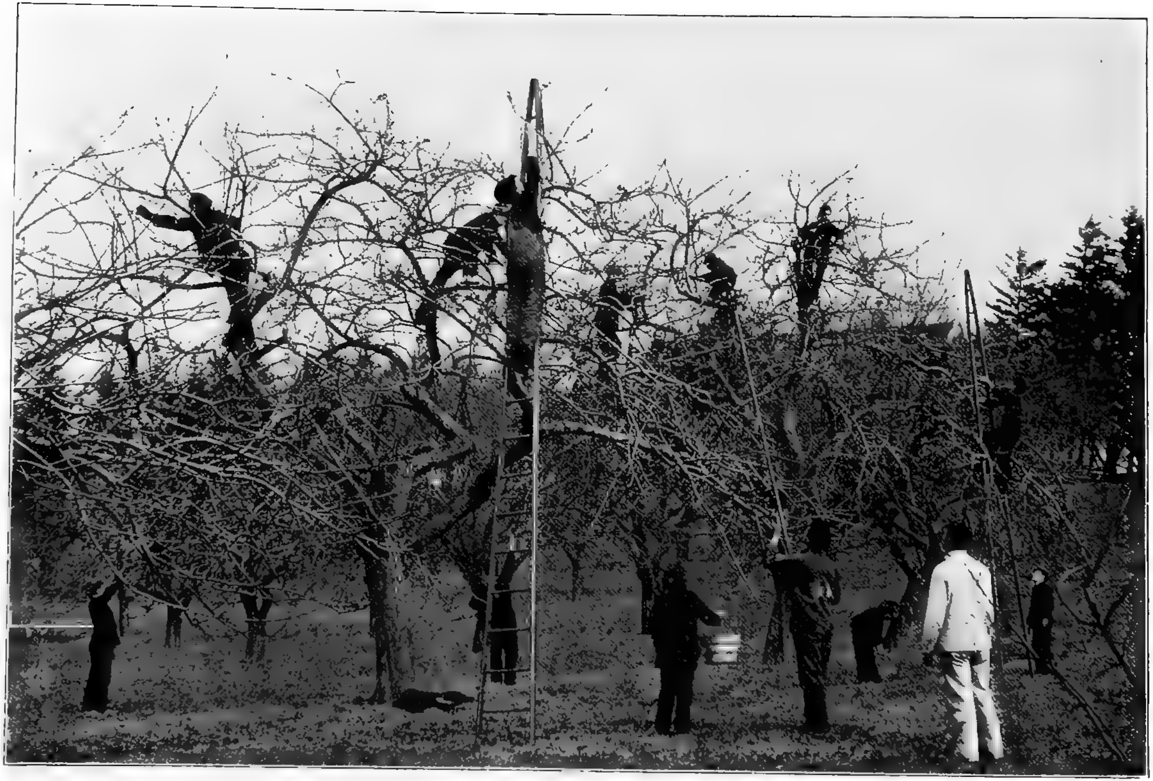
The Brown-tail Moth.

The Eggs. — The gathering of leaves which bear egg masses is only feasible in the case of shrubs and young trees where the foliage may be reached from the ground. Rose bushes, dwarf fruit trees and ornamental shrubs often may be cleared from the moth in this way.

The Caterpillar. — The winter webs or nests containing the hibernating caterpillars are conspicuous objects at the tips of twigs from October to April. These webs should be sought out



Thousands of gypsy moth caterpillars clustered at base of banded tree. The dark portion of the trunk indicates the mass of caterpillars whose farther ascent is prevented by the sticky band. Arlington, June, 1905.



Pupils of Farm School, Thompson's Island, destroying winter webs of brown-tail moth, December, 1902.

Photo loaned by Chas. Bradley, Superintendent of Farm School.

Massachusetts Board of Agriculture, Special Report on Brown-tail Moth, 1903.

and removed by the use of pole shears or long-handled pruners, and then carefully collected and burned. It is more satisfactory, where possible, to burn the webs in a furnace or stove, since, where an open bonfire is used, extra care must be taken to see that none of the webs escape with a mere scorching. When a light snow is on the ground, the work of web destruction and gathering can be carried on to best advantage, although it is desirable that the work should be done as early as possible in the season after the leaves fall. Where tall trees are infested, two men, one to point out the nests from the ground, the other in the tree to cut off the nests, can work more rapidly and economically than one man. It should be borne in mind that webs cut off and thrown on a dump heap as well as those that are beaten off by storms will yield their quota of caterpillars the following spring.

Of all means of combating the brown-tail moth, web destruction as above outlined is the remedy *par excellence.*

Spraying is very effective against brown-tail moth caterpillars, since they are much less resistant to the action of poison than are those of the gypsy moth. To secure best results, spraying should be done as soon as the foliage develops in the spring. Five to eight pounds of the arsenate of lead paste to one hundred gallons of water is sufficient for the spray, or, if preferred, one pound of good Paris green kept well stirred in one hundred and fifty gallons of water may be applied. The directions given for spraying gypsy moth caterpillars should be followed in the case of those of the brown-tail moth. Spraying may be done not only in the spring, but also in August when the caterpillars hatch from the egg, except in cases of trees in fruit.

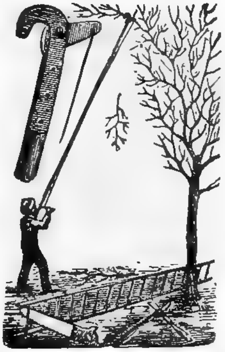


Fig. 9.—Pruning shears suitable for removal of winter webs.

Spraying or sprinkling with kerosene emulsion or strong soap suds is often useful in destroying the swarming caterpillars on fences, walks, etc.

Such trees as are free from brown-tail moths may be protected from the caterpillars which crawl from neighboring estates by applying a sticky band. The banding will not prevent the infestation of the trees by the female winged moths, which, flying in July, will alight on the foliage of such trees and deposit their egg clusters thereon. It is therefore clear that sticky banding, when used against brown-tail caterpillars, has a more strictly limited usefulness than in the case of the gypsy moth.

The Pupæ. — When the caterpillars have changed to pupæ enclosed by their cocoons, these may be gathered, although the work is likely to be attended by severe inflammation of the skin from contact with the nettling hairs. Cocoons thus gathered should be placed in a barrel covered with mosquito netting, so that any parasites may escape while the moths are confined. Brown-tail moth pupæ are most numerous during the latter half of June.

The Moths. — As has been already mentioned, the moths assemble in great numbers around electric and other lights. It often occurs on a morning during the flying season that a lamp pole is covered by hundreds if not thousands of the winged moths. In such cases the free use of the hose will wash down and kill the insects. No effective form of lamp trap has yet been devised, and, in fact, it is not at all clear that the brown-tail moth can be combated economically in the winged stage.

INSECTS MISTAKEN FOR THE GYPSY AND BROWN-TAIL MOTHS.

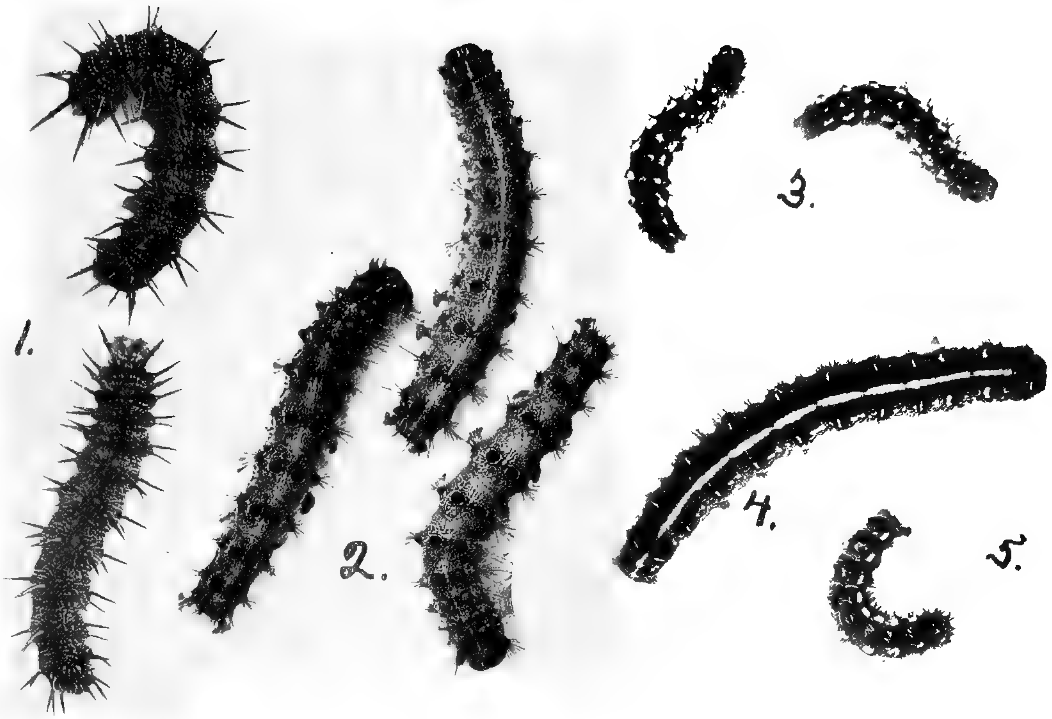
Owing to the growing public interest in injurious insects, doubtless due in part to the fear of the moth pests, it seems desirable to include at this point a brief description of the insects commonly mistaken for either gypsy or brown-tail moths, together with the remedies applicable to each species.

Tent Caterpillar.

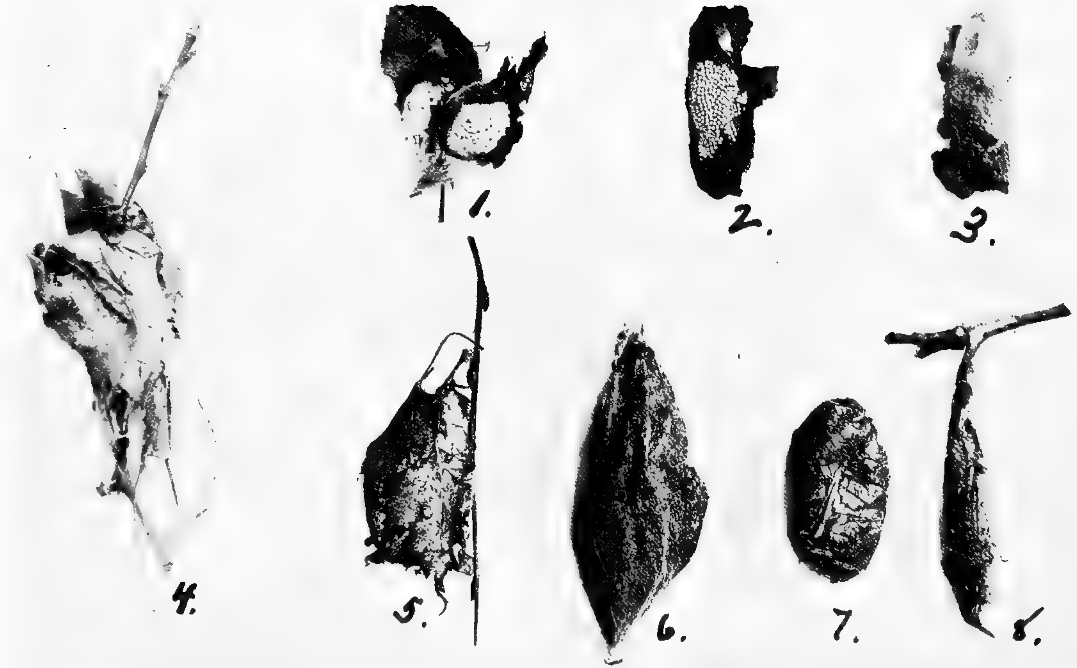
Eggs: laid in midsummer in a compact, varnish-covered band around twigs of apple, wild cherry, etc. *Larva:* appears late in April, and feeds to June 1–10. The full-grown caterpillar has a conspicuous, light yellow stripe along the back, which distinguishes it from the larva of the gypsy or of the brown-tail moth; the white webs spun by the caterpillars in the forks of branches also serve to distinguish this species from the two others. *Cocoon:* cream colored, containing a notable quantity of sulphur yellow powder, spun on bark, fences or other sheltered places. *Moth:* reddish brown, spread about ¾ to 1 inch, flying principally by night. *Remedy:* spray with arsenate of lead, 3 pounds to 50 gallons of water, as soon as webs are noticed.

Forest Tent Caterpillar.

Eggs: laid on twigs of forest trees, the ends of the egg band being square cut instead of rounded, as in preceding species. *Larva:* conspicuously marked with a broken row of cream colored spots along back; other stages similar to preceding species. These



1. Vanessa larvæ. 2 Gypsy moth larvæ. 3 and 5. Brown-tail moth larvæ.
4. Tent caterpillar (slightly enlarged).



Egg clusters mistaken for that of the gypsy moth.
  1. Orgyia leucostigma.
  2. O. antiqua.
  3. O definita.
4. Brown-tail moth web.

Cocoons mistaken for brown-tail moth web.
  5. Actias luna.
  6. Attacus cecropia.
  7. Telea polyphemus.
  8. Callosamia promethea.

insects sometimes cause severe damage to sugar orchards. *Remedy:* spray about May 15 with arsenate of lead, 3 pounds to 50 gallons of water.

Canker Worms.

These insects of two similar species are true loopers or inch worms. *Eggs:* laid in small masses on bark of infested trees in fall or spring. *Larva:* generally dark colored, with variable faint yellowish stripes. The feeding period extends from May 1 to about June 20, badly infested trees appearing as if swept by fire. *Pupa:* formed in an earthen cell at variable depth in the ground. *Moth:* ashy gray in case of male, dull gray in case of female which is wingless, and is obliged to crawl up the tree in order to deposit her eggs. *Remedies:* banding the trees with sticky materials in November will intercept the female moths of the fall species. The same treatment repeated in March and April will prevent the ascent of the spring canker worm. Spraying about May 15 with arsenate of lead, 3 pounds to 50 gallons of water, is also an effective remedy.

Plant Lice.

These insects feed on plant juices, and are best combated by spraying with kerosene emulsion, 1 part to 9 of water, or with whale oil soap, 1 pound to 8 gallons of water. The elm leaf louse curls the terminal leaves of elm twigs early in the spring. A like effect is produced on the apple by the common green aphis, and the cherry and peach are afflicted by a plant louse of similar habits. The important thing in treating these insects is to drive the spray forcibly into the curled leaves, and to make a second treatment about one week after the first spraying. With plant lice it is a general rule that by midsummer their natural enemies develop in sufficient numbers to check their increase.

Spiny Elm Caterpillar (*Vanessa*).

Eggs: laid early in the spring in a band around twigs of elm, willow or poplar. *Larva:* the dark colored spiny caterpillars feed in clusters, and commonly strip one or more branches by June 25 at about which date they descend the trees to transform. Occasionally an entire tree is defoliated. *Pupa:* dull grayish, armed with short spines; usually found under fences and in sheltered places. *Butterfly:* expands 2½ inches, very dark brown with a conspicuous yellow border. The second brood of caterpillars appears in August, and the butterflies winter under bark, in walls, etc. *Remedy:* the caterpillars may be jarred off and crushed under foot, or the branch which they infest may be cut off and burned. Spraying with arsenate of lead, 3 pounds to 50 gallons of water, is completely effective.

Tussock Moth (*Orgyia*).

Eggs: laid in a white, froth-covered mass on the old cocoon on the bark of elm, horse chestnut, pear and other trees. *Larva:* appears about June 1st, and when full grown is yellowish gray in color with a red head and with two pencils of black hair pointing forward from the head and a single pencil pointing backward from the tip of the body. There are also four dense tufts of white hair on the back. *Cocoon:* spun on bark, fences and house walls. *Moth:* the male is of a chocolate brown color and expands about ¾ inch; female, light gray, spider-like and wingless. There is usually a second brood in late summer. Of the two allied species *O. definita* covers the egg mass with brownish hair and has a conspicuously yellow caterpillar, while *O. antiqua* lays a naked egg mass and has dark colored caterpillars. The latter species is most common on the apple and the willow. *Remedy:* creosote, or collect and burn the egg mass in the winter; spray with arsenate of lead, 3 pounds to 50 gallons of water, as soon as the small caterpillars are noticed.

Imported Elm Leaf Beetle.

Eggs: laid in June in small, compact clusters on under side of leaf of elm. The egg clusters resemble those of the potato beetle but are smaller and of a lighter yellow color. *Larva:* the slugs feed almost wholly on the lower side of the leaf, consuming the epidermis and leaf tissue. By July 15 infested trees often appear as if swept by fire. When full grown the slugs are about ½ inch long and are light yellow in color with black markings on either side of the body. *Pupæ:* small, orange colored bodies, found in great masses at base of tree or in rough bark. *Beetle:* about ⅓ inch long, dull smoky yellow, with dark bordered wings. A partial second brood occurs in some seasons. The mature beetle hibernates under shingles and clapboards of buildings, under rough bark and in various sheltered places. Their early feeding in spring causes the trees to appear as if riddled by shot. *Remedy:* spray early in June with arsenate of lead, 5 pounds to 50 gallons of water. Use kerosene emulsion, strong soap suds, or hot water on the masses of pupæ around the base of infested trees. The principal dependence must be put on spraying.

Web Worm.

The fall web worm is often mistaken for the brown-tail moth caterpillar, but its webs are larger and much more conspicuous. *Eggs:* laid by the moth in a small patch on the under side of the leaf of various trees late in June. *Larva:* feeds within a web which by late summer is often several feet in diameter. The full grown caterpillar is about 1½ inches long with yellowish, longitudinal markings and clothed with slender grayish hairs. In September the caterpillars pupate in the ground to emerge as snow white moths in early summer. *Remedy:* spray with arsenate of lead, 3 pounds to 50 gallons of water, as soon as the first webs are noticed. Trees of which the fruit is nearly ripe should not be sprayed; in this case the judicious use of the torch is recommended.

Fall Caterpillars.

Several species of caterpillars appearing in August – September are often mistaken for those of the gypsy moth, and may be treated collectively. The red-humped apple worm occurs principally on the apple, is about 1½ inches long, and is characterized by a conspicuous, transverse, red hump near the head. The *Datanas* of several species are slightly larger than the preceding, feed in clusters on the apple, hickory, etc., and have the habit of raising both ends of the body when disturbed. The species most common on fruit trees is dark yellow with numerous fine black lines, while another often abundant on forest trees is black with conspicuous white hairs. The characteristics mentioned distinguish them from the gypsy moth caterpillars. *Remedy:* pray with arsenate of lead, 5 pounds to 50 gallons of water; ecommended except on trees with fruit nearly ripe. In this ase the torch may be carefully used, or the caterpillars may be jarred off and crushed under foot.

A SUMMARY OF THE LAW.

In the suppression of the gypsy and brown-tail moths, certain duties under the law devolve not only upon the Commonwealth but also upon cities and towns and upon citizens as individuals. Attention is hereby called to chapter 381, Acts of 1905, as amended by chapter 268, Acts of 1906, which defines these duties at length and which is printed in full at the end of this bulletin.

The following summary of the law is designed to give its salient points:—

The Moths are Public Nuisances.

The gypsy and brown-tail moths are declared public nuisances and their suppression is required.

The Superintendent of Suppression.

A superintendent, appointed by the Governor, with power, subject to the Governor's approval, of appointing agents and assistants, has entire general charge of the work of suppressing the moths.

Duties of Cities, Towns and Individuals.

Cities and towns (under the advice and general direction of the superintendent, and by such agent as they may designate or appoint) are required, under penalty for neglect, to destroy the eggs, caterpillars, pupæ and nests of the gypsy and the brown-tail moths within their limits:

Excepting that such work is not to be done by cities and towns on property controlled by the Commonwealth; nor is it to be done upon private property, excepting where the owners of the same fail to destroy the eggs, caterpillars, pupæ and nests of the moths, in accordance with the terms of the official notice to private owners, noted in the section here following: —

Notice to Private Owners.

The mayor of every city and the selectmen of every town shall, at suitable times, notify every owner of land located therein which is infested with the moths, requiring him to destroy the eggs, caterpillars, pupæ and nests of the moths within a specified time.

When the mayor or selectmen decide that the cost of such destruction (on lands contiguous and under one ownership) will exceed one-half of one per cent of the assessed valuation of the lands, then they may designate in the notice a part only of such lands on which the destruction shall take place.

Failure of Private Owners to destroy Moths.

If the owner does not, as required by the terms of the aforesaid notice, destroy the eggs, caterpillars, pupæ and nests of the moths, then the city or town, subject to the approval of the state superintendent, shall destroy them, and shall assess upon such aforesaid lands the actual cost of so doing, to an amount, however, not exceeding one-half of one per cent of the assessed valuation of the land.

This amount, so assessed, shall be collected in the form of taxes, and constitutes a lien upon such lands.*

Redress by Abatement and Appeal.

The assessors may abate the moth assessment in the case of any private land owner decided by them to be unable to pay it because of age, infirmity or poverty.

Appeal to the county superior court, with special provision for prompt hearing, is provided by the statute for any person aggrieved by assessment on account of this work; provided a complaint is entered within thirty days of notice of such assessment.

Appropriation by the Commonwealth.

To meet the expenses incurred under its moth-suppression law, the Commonwealth appropriated in 1905 $300,000, of which $75,000 might be expended during 1905, $150,000 (and any unexpended balance) during 1906, and $75,000 (and any unexpended balance) during 1907, up to May 1, 1907, inclusive.†

For the purpose of experimenting with natural enemies for destroying the moths, $10,000 was additionally appropriated for each of the years 1905, 1906 and 1907.

Reimbursements to Cities and Towns.

1. Cities and towns with valuation of real and personal estate of $12,500,000 or more, having spent $5,000 in any one calendar year, shall be reimbursed annually 50 per cent (one-half) of all further expenditure.

2. Cities and towns, with valuation less than $12,500,000 and more than $6,000,000, having spent an amount equal to one-twenty-fifth of one per cent of such valuation in one year, shall be reimbursed annually 80 per cent (four-fifths) of all further expenditure.

3. Towns with valuation less than $6,000,000, having spent an amount equal to one-twenty-fifth of one per cent of such valuation in one year, shall be reimbursed once in sixty days for *all* further expenditure.

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* By a recent ruling of the Attorney-General the word "lands" is held to include lands with buildings thereon.

† An additional appropriation of $75,000 for suppressing the gypsy and brown-tail moths was made by the legislature, May 8, 1906.

Limits to required Expenditure by Cities and Towns.

No city or town with an assessed real and personal valuation of *more* than $6,000,000 shall be required to expend in the suppression of the moths during any one full year more than one-fifteenth of one per cent of such valuation. No town with an assessed real and personal valuation of *less* than $6,000,000 shall be required to thus expend during any one full year more than one-twenty-fifth of one per cent of such valuation.

Valuations of 1904 taken as a Basis.

Wherever valuations of real and personal property are referred to in the gypsy and brown-tail moth suppression law, the valuations of 1904 are meant.

Wilful Resistance and Failure to comply with Rules.

A person who wilfully resists or obstructs any agent of the Commonwealth or of any city or town while lawfully engaged in the execution of the purposes of the act relative to suppressing the moths, or who knowingly fails to comply with any of the rules or regulations issued by the superintendent shall forfeit a sum not exceeding $25 for each offence.

PENALTY FOR TRANSPORTING MOTHS.

[SEC. 108, CHAP. 208, REVISED LAWS.]

Whoever knowingly brings the insects which are known as the ocneria dispar or gypsy moth or as the brown-tail moth, or their nests or eggs, into this commonwealth, or whoever knowingly transports said insects or their eggs or nests from one city or town to another city or town in the commonwealth, except when engaged in, and for the purpose of, destroying them shall be punished by a fine of not more than two hundred dollars or by imprisonment for not more than sixty days, or by both such fine and imprisonment.

[UNITED STATES STATUTES AT LARGE, VOL. 33, PART 1, CHAP. 1501. AN ACT TO PROHIBIT IMPORTATION OR INTERSTATE TRANSPORTATION OF INSECT PESTS AND THE USE OF THE UNITED STATES MAILS FOR THAT PURPOSE.]

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That no railroad, steamboat, express, stage or other transportation company shall knowingly transport from one State or Territory into any other State or Territory, or from the District of Columbia into a State or Territory, or from a State or Territory into the District of Columbia, or from a foreign country into the United States, the gypsy moth, brown-tail moth, leopard moth, plum curculio, hop plant-louse, boll weevil, or any of them in a live state, or other insect in a live state which is notoriously injurious to cultivated crops, including vegetables, field crops, bush fruits, orchard trees, forest trees, or shade trees; or the eggs, pupæ, or larvæ of any insect injurious as aforesaid, except when shipped for scientific purposes under the regulations hereinafter provided for; nor shall any person remove from one State or Territory into another State or Territory, or from a foreign country into the United States, or from a State or Territory into the District of Columbia, or from the District of Columbia into any State or Territory, except for scientific purposes under the regulations hereinafter provided for, the gypsy moth, brown-tail moth, leopard moth, plum curculio, hop plant-louse, boll weevil, or any of them in a live state, or other insect in a live state which is notoriously injurious to cultivated crops, including vegetables, field crops, bush fruits, orchard trees, forest trees, or shade trees; or the eggs, pupæ, or larvæ of any insect injurious as aforesaid.

SEC. 2. That any letter, parcel, box, or other package containing the gypsy moth, brown-tail moth, leopard moth, plum curculio, hop plant-louse, boll weevil, or any of them in a live state, or other insect in a live state which is notoriously injurious to cultivated crops, including vegetables, field crops, bush fruits, orchard trees, forest trees, or shade trees, or any letter, parcel, box, or package which contains the eggs, pupæ, or larvæ of any insect injurious as aforesaid, whether sealed as first-class matter or not, is hereby declared to be nonmailable matter, except when mailed for scientific purposes under the regulations hereinafter provided for, and shall not be conveyed in the mails, nor delivered from any post-office, nor by any letter carrier, except when mailed for scientific purposes under the regulations hereinafter provided for; and any person who shall knowingly deposit, or cause to be deposited, for mailing or delivery, anything declared by this section to be nonmailable matter, or cause the same to be taken from the mails for the purpose of retaining, circulating, or disposing of, or of aiding in the retention, circulation, or disposition of the same shall, for each and every offense, be fined, upon conviction thereof, not more than five thousand dollars or imprisoned at hard labor not more than five years, or both, at the discretion of the court: Provided, That nothing in this Act shall authorize any person to open any letter or sealed matter of the first-class not addressed to himself.

SEC. 3. That it shall be the duty of the Secretary of Agriculture, and he is hereby authorized and directed to prepare and promulgate rules and regulations under which the insects covered by sections one and two of this Act may be mailed, shipped, transported, delivered, and removed, for scientific purposes, from one State or Territory into another State or Territory, or from the District of Columbia into a State or Territory, or from a State or Territory into the District of Columbia, and any insects covered by sections one and two of this Act may be so mailed, shipped, transported, delivered, and removed, for scientific purposes, under the rules and regulations of the Secretary of Agriculture: Provided, That the rules and regulations of the Secretary of Agriculture, in so far as they affect the method of mailing insects, shall be approved by the Postmaster-General, and nothing in this Act shall be construed to prevent any State from making and enforcing laws in furtherance of the purpose of this Act, prohibiting or regulating the admission into that State of insects from a foreign country.

SEC. 4. That any person, company, or corporation who shall knowingly violate the provisions of section one of this Act shall, for each offense, be fined, upon conviction thereof, not more than five thousand dollars or imprisoned at hard labor not more than five years, or both, at the discretion of the court.

Approved, March 3, 1905.

WARNING.

Many property owners prefer to hire experts to destroy the moth pests on their estates, and this is often the most economical and effective plan, particularly in the case of the gypsy moth. This office has prepared a list of reliable persons who are engaged in the work of moth suppression as a business, and the same may be had on request. It should be understood, however, that the superintendent assumes no responsibility for the success or the cost of such work.

It is to be regretted that several unscrupulous persons have made a practice of applying worthless treatment to trees, at large cost to the owner, and even, in some cases, have claimed that they were official representatives of this office. It should be clearly understood that no employee of this office is authorized to do such work, to be paid for directly by property owners. Any case of a person making representations to the contrary should be brought to the attention of the police and this office notified.

The superintendent has organized a small corps of trained agents and inspectors who are engaged in examining the infested territory and in directing the work of the various cities and towns. The central office is prepared to advise officials in charge of local work, as well as private citizens, concerning the best methods of combating the moths, and to render any assistance in its power.

If our trees are to be saved from these insects, the hearty co-operation of all citizens will be necessary. Without such co-operation little can be accomplished; with it, the pests can be brought under control.

A. H. KIRKLAND,
Superintendent.

OFFICE, 6 BEACON STREET, BOSTON, MASS.

Connected by telephone.

LAW RELATING

TO

GYPSY AND BROWN TAIL MOTHS.

[CHAP. 381, ACTS OF 1905, AS AMENDED BY CHAP. 268, ACTS OF 1906.]

AN ACT TO PROVIDE FOR SUPPRESSING THE GYPSY AND BROWN TAIL MOTHS.

Be it enacted, etc., as follows:

SECTION 1. For the purposes of this act the pupæ, nests, eggs and caterpillars of the gypsy and brown tail moths and said moths are hereby declared public nuisances, and their suppression is authorized and required; but no owner or occupant of an estate infested by such nuisance shall by reason thereof be liable to an action, civil or criminal, except to the extent and in the manner and form herein set forth.

SECTION 2. The governor, by and with the consent of the council, shall appoint a superintendent for suppressing the gypsy and brown tail moths and shall determine his salary. The governor may, with the consent of the council, remove said superintendent at any time for such cause as he shall deem sufficient. In case of the death, removal or resignation of the superintendent the governor shall forthwith appoint a successor. On or before the third Wednesday in January in each year the superintendent shall make a report of his proceedings to the general court, which shall be a public document and shall be printed. Said report shall separate so far as is practicable the expenditures on work against the gypsy moth from those on work against the brown tail moth in each city and town.

SECTION 3. [As amended by section 1, chapter 268, Acts of 1906.] The said superintendent shall act for the Commonwealth in suppressing said moths as public nuisances, in accordance with the provisions of this act. For this purpose he shall establish an office and keep a record of his doings and of his receipts and expenditures, and may, subject to the approval of the governor, make rules and regulations governing all operations by cities, towns or individuals under this act. He may employ such clerks, assistants and agents, including expert advisers and inspectors, as he may deem necessary and as shall be approved by the governor. He may make contracts on behalf of the Commonwealth; may act in co-operation with any person, persons, corporation or corporations, including other states, the United States or foreign governments; may conduct investigations and accumulate and distribute information concerning said moths; may devise, use and require all other lawful means of suppressing or preventing said moths; may lease real estate when he deems it necessary, and, with the approval of the board in charge, may use any real or personal property of the Commonwealth; may at all times enter upon the land of the Commonwealth or of a municipality, corporation, or other owner or owners, and may use all reasonable means in carrying out the purposes of this act; and, in the undertakings aforesaid, may, in accordance with the provisions of this act, expend the funds appropriated or donated therefor; but no expenditure shall be made or liability incurred in excess of such appropriations and donations.

SECTION 4. [As amended by section 2, chapter 268, Acts of 1906.] Cities and towns by such public officer or board as they shall designate or appoint, shall, under the advice and general direction of said superintendent, destroy the eggs, caterpillars, pupæ and nests of the gypsy and brown tail moths within their limits, except in parks and other property under the control of the Commonwealth, and except in private property, save as otherwise provided herein. When any city or town shall have expended within its limits city or town funds to an amount in excess of five thousand dollars in any one calendar year, in suppressing gypsy or brown tail moths, the Commonwealth shall reimburse such city or town to the extent of fifty per cent of such excess above said five thousand dollars.

Cities or towns, where one twenty-fifth of one per cent of the assessed valuation of real and personal property is less than five thousand dollars, and where the assessed valuation of real and personal property is greater than six million dollars, shall be reimbursed by the Commonwealth to the extent of eighty per cent of the amount expended by such cities or towns of city or town funds in suppressing the gypsy and brown tail moths in any one calendar year, in excess of said one twenty-fifth of one per cent.

In the case of towns where the assessed valuation of real and personal property is less than six million dollars, after they have expended in any one calendar year town funds to an amount equal to one twenty-fifth of one per cent of their assessed valuation of real and personal property, the Commonwealth shall expend within the limits of such towns, for the purpose of suppressing the gypsy and brown tail moths, such an amount in addition as the superintendent with the advice and consent of the governor shall recommend. Disbursements made by said last named towns in excess of said one twenty-fifth of one per cent shall be reimbursed by the Commonwealth every sixty days; but in the case of all others the Commonwealth shall reimburse cities and towns annually according to the provisions of this act.

No city or town shall be entitled to any reimbursement from the Commonwealth until it has submitted to the auditor of the Commonwealth itemized accounts and vouchers showing the definite amount expended by it for the purpose of this act; nor shall any money be paid out of the treasury of the Commonwealth to cities or towns, pursuant to the provisions of this act, until said vouchers and accounts have been approved by the superintendent and the auditor of the Commonwealth.

For the purposes of this section the years nineteen hundred and five and nineteen hundred and seven shall be considered half years, and the valuation for the year nineteen hundred and four shall be taken as a basis.

SECTION 5. [As amended by section 3, chapter 268, Acts of 1906.] When, in the opinion of the superintendent, any city or town is not expending a sufficient amount for the abatement of said nuisance, or is not conducting the necessary work in a proper manner, then the superintendent shall, with the advice and consent of the governor, order such city or town to expend such an amount as the superintendent shall deem necessary, and in accordance with such methods as the superintendent, with the consent of the governor, shall prescribe: *provided,* that no city or town where the assessed valuation of real and personal property exceeds six million dollars shall be required to expend, exclusive of any reimbursement received from the Commonwealth, during any one full year more than one fifteenth of one per cent of such valuation, and that no town where the assessed valuation of real and personal property is less than six million dollars shall be required to expend, exclusive of any reimbursement received from the Commonwealth, during any one full year more than one twenty-fifth of one per cent of such valuation. For the purposes of this section the valuation of the year nineteen hundred and four shall be used.

Any city or town failing to comply with the directions of the said superintendent in the performance of said work within the date specified by him shall pay a fine of one hundred dollars a day for failure so to do; said fine to be collected by information brought by the attorney-general in the supreme judicial court for Suffolk county.

SECTION 6. [As amended by section 4, chapter 268, Acts of 1906.] The mayor of every city and the selectmen of every town shall, on or before the first day of November in each year, and at such other times as he or they shall see fit, or as the state superintendent may order, cause a notice to be sent to the owner or owners, so far as can be ascertained, of every parcel of land therein which is infested with said moths; or, if such notification appears to be impracticable, then by posting such notice on said parcels of land, requiring that the eggs, caterpillars, pupæ and nests of said moths shall be destroyed within a time specified in the notice.

When, in the opinion of the mayor or selectmen, the cost of destroying such eggs, caterpillars, pupæ and nests on lands contiguous and held under one ownership in a city or town shall exceed one half of one per cent of the assessed value of said lands, then a part of said premises on which said eggs, caterpillars, pupæ or nests shall be destroyed may be designated in such notice, and such requirement shall not apply to the remainder of said premises. The mayor or selectmen may designate the manner in which such work shall be done, but all work done under this section shall be subject to the approval of the state superintendent.

If the owner or owners shall fail to destroy such eggs, caterpillars, pupæ or nests in accordance with the requirements of the said notice, then the city or town, acting by the public officer or board of such city or town designated or appointed as aforesaid, shall, subject to the approval of the said superintendent, destroy the same, and the amount actually expended thereon, not exceeding one half of one per cent of the assessed valuation of said lands, as heretofore specified in this section, shall be assessed upon the said lands; and such an amount in addition as shall be required shall be apportioned between the city or town and the Commonwealth in accordance with the provisions of section four of this act. The amounts to be assessed upon private estates as herein provided shall be assessed and collected, and shall be a lien on said estates, in the same manner and with the same effect as is provided in the case of assessments for street watering.

SECTION 7. [As amended by section 5, chapter 268, Acts of 1906.] If, in the opinion of the assessors of a city or town, any land therein has received, by reason of the abatement of said nuisances thereon by said superintendent or by said city or town, a special benefit beyond the general advantage to all land in the city or town, then the said assessors shall determine the value of such special benefit and shall assess the amount thereof upon said land: *provided,* that no such assessment on lands contiguous and held under one ownership shall exceed one half of one per cent of the assessed valuation of said lands; and *provided,* that the owner or owners shall have deducted from such assessment the amount paid and expended by them during the twelve months last preceding the date of such assessment toward abating the said nuisances on said lands, if, in the opinion of the assessors, such amount has been expended in good faith. Such assessment shall be a lien upon the land for three years from the first day of January next after the assessment has been made, and shall be collected under a warrant of the assessors to the collector of taxes of such city or town, in the manner and upon the terms and conditions and in the exercise of the powers and duties, so far as they may be applicable, prescribed by chapter thirteen of the Revised Laws relative to the collection of taxes.

Real estate sold hereunder may be redeemed within the time, in the manner, and under the provisions of law, so far as they may be applicable, set forth in chapter thirteen of the Revised Laws for the redemption of land sold for taxes.

A person aggrieved by such assessment may appeal to the superior court for the county in which the land lies, by entering a complaint in said court within thirty days after he has had actual notice of the assessment, which complaint shall be determined as other causes by the court without a jury. The complaint shall be heard at the first sitting of said court for trials without a jury after its entry; but the court may allow further time, or may advance the case for speedy trial, or may appoint an auditor as in other cases. The court may revise the assessment, may allow the recovery back of an amount wrongfully assessed which has been paid, may set aside, in a suit begun within three years from the date thereof, a collector's sale made under an erroneous assessment, may award costs to either party and may render such judgment as justice and equity require.

If, in the opinion of the assessors, the owner of an estate upon which an assessment as aforesaid has been made is, by reason of age, infirmity or poverty unable to pay the assessment, they may upon application abate the same. Every city or town in rendering an account to the state auditor as provided for in section four of this act shall deduct from such amount as it has expended the total amount it has received for work performed under section six of this act during the term covered by the account: *provided,* such work was performed under such conditions as require reimbursement in whole or in part by the state.

SECTION 8. To meet the expenses incurred under authority of this act, there shall be allowed and paid out of the treasury of the Commonwealth, during the period up to and including May first, nineteen hundred and seven, the sum of three hundred thousand dollars. Of this amount seventy-five thousand dollars may be expended during the calendar year nineteen hundred and five; one hundred and fifty thousand dollars, and any unexpended balance of the previous year, may be expended during the calendar year nineteen hundred and six; and seventy-five thousand dollars, and any unexpended balance of the previous years, may be expended during the calendar year nineteen hundred and seven, up to and including May first.

SECTION 9. An additional sum of ten thousand dollars in each of the years nineteen hundred and five, nineteen hundred and six and nineteen hundred and seven may, in the discretion of the state superintendent, be expended by him for experimenting with parasites or natural enemies for destroying said moths, and any unexpended balance of any year may be expended in the subsequent years.

SECTION 10. Chapter two hundred and ten of the acts of the year eighteen hundred and ninety-one and sections one and two of chapter five hundred and forty-four of the acts of the year eighteen hundred and ninety-eight and section two of chapter fifty-seven of the acts of the year nineteen hundred and two, are hereby repealed.

SECTION 11. [As amended by section 6, chapter 268, Acts of 1906.] A person who wilfully resists or obstructs the superintendent or an official of a city or town, or a servant or agent duly employed by said superintendent or by any of said officials, while lawfully engaged in the execution of the purposes of this act, or who knowingly fails to comply with any of the rules or regulations issued by said superintendent, shall forfeit a sum not exceeding twenty-five dollars for each offence.

SECTION 12. Valuations of real and personal property of the year nineteen hundred and four shall govern the provisions of this act.

SECTION 13. This act shall take effect upon its passage. [*Approved May 8, 1905.*

Issued December 8, 1910.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—CIRCULAR No. 128.
L. O. HOWARD, Entomologist and Chief of Bureau.

INSECT INJURIES TO FOREST PRODUCTS.

BY

A. D. HOPKINS,
In Charge of Forest Insect Investigations.

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CIRCULAR No. 128. Issued December 8, 1910.

United States Department of Agriculture,

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

INSECT INJURIES TO FOREST PRODUCTS.[a]

By A. D. HOPKINS,
In Charge of Forest Insect Investigations.

Damage is caused by various species of insects which are attracted by the varying conditions prevailing at different stages during the process of utilizing the forest resources, from the time the trees are felled until the logs are converted into the crude and finished product and until the latter reaches the final consumer, or even after it is placed in the finished article or structure. As a result, additional drains are made on the timber to meet the demand for the higher grades of lumber and for other supplies to replace those injured or destroyed. From the writer's personal investigations of this subject in different sections of the country it is evident that the damage to forest products of various kinds from this cause is far more extensive than is generally recognized. This loss differs from that resulting from insect damage to standing timber in that it represents more directly a loss of money invested in material and labor.

CRUDE PRODUCTS.

Roundheaded borers, timber worms, and ambrosia beetles.—Round timber with the bark on, such as poles, posts, mine props, saw logs, etc., is subject to serious damage by the same class of insects as those mentioned under injury to the wood of dying and dead trees. The damage is especially severe when material is handled in such a manner as to offer favorable conditions for attack, as when the logs are left in the woods on skidways or in millyards for a month or more after they have been cut from the living trees. Under such conditions there is often a reduction in value of from 5 to 30 per cent or more, due to wormhole and pinhole defects caused by roundheaded and flatheaded wood-borers and timber beetles. Frequently the insects continue the work in the unseasoned and even dry lumber cut from logs which had been previously infested. They also continue to work in mine props after they have been placed in the mine, and in logs and other material used for the construction of cabins, rustic houses, etc., and in round timbers generally.

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[a] Revised extracts from Bulletin No. 58, Part V, Bureau of Entomology, U. S. Department of Agriculture, 1909.

The products from saplings, such as hickory hoop poles and like material, are often seriously injured or rendered worthless by roundheaded and flatheaded borers and wood-boring beetles, sometimes resulting in a loss of from 50 to 100 per cent of the merchantable product.

Stave and shingle bolts left in moist, shady places in the woods or in close piles during the summer months are often attacked by ambrosia beetles and timber beetles. The value of the product is often reduced, as a consequence, from 10 to 50 per cent or more.

Handle and wagon stock in the rough is especially liable to injury by ambrosia beetles and roundheaded borers. Hickory and ash bolts from which the bark is not removed are almost certain to be greatly damaged if the logs and bolts cut from living trees during the winter and spring are held over for a few weeks after the middle of March or first of April.

Pulp wood, and cord wood for fuel and other purposes, cut during the winter and spring and left in the woods for a few weeks or months or in close piles after the beginning of the warm weather, are sometimes riddled with wormholes or converted into sawdust borings, causing a loss of from 10 to 100 per cent. One example reported from near Munising, Mich., represents a loss of $5,000 from injury to spruce and fir pulp wood cut in the winter and kept in piles over summer.

MANUFACTURED UNSEASONED PRODUCTS.

Ambrosia beetles and other wood borers.—Freshly sawed hardwood placed in close piles during warm, damp weather during the period from June to September is often seriously injured by ambrosia beetles. Heavy 2-inch to 3-inch stuff is also liable to attack by the same insects, even in loose piles. An example of this was found in some thousands of feet of mahogany lumber of the highest grade, which had been sawed from imported round logs and piled with lumber sticks between the tiers of plank. Native species of ambrosia beetles had entered the wood to such an extent as to have reduced the value 50 per cent or more within a few weeks. Oak, poplar, gum, and similar woods often suffer severely from this class of injury, causing losses varying from 5 to 50 per cent.

Lumber and square timbers of both soft and hard woods with the bark left on the edges are frequently damaged by flatheaded and roundheaded wood borers, which hatch from eggs deposited in the bark before or after the lumber is sawed. There are examples of losses from this character of injury amounting to from 20 to 50 per cent or more.

Telegraph and telephone poles, posts, mine props, etc., are frequently injured before they are set in the ground, especially if the bark remains on them during a few weeks after the middle of March.

SEASONED PRODUCTS IN YARDS AND STOREHOUSES.

Powder-post beetles.—Hardwood lumber of all kinds, rough handles, wagon stock, etc., made partially or entirely of sapwood, are often reduced in value from 10 to 90 per cent by a class of insects known as powder-post beetles. The sapwood of hickory, ash, and oak is most liable to attack. The reported losses from this source during the past five or six years indicate that there has been an average reduction in values of from 5 to 10 per cent or more.

Old hemlock and oak tanbark is often so badly damaged by various insects which infest dead and dry bark that in some tanyards as much as 50 to 75 per cent of the bark that is over three years old is destroyed. In one tannery in West Virginia it is estimated that more than $30,000 worth of hemlock bark was thus destroyed.

FINISHED PRODUCTS.

The greatest loss of finished hardwood products, such as handle, wagon, carriage, and machinery stock, is caused by powder-post beetles. This is especially true of hickory and ash handles and like products in the large and small storehouses of the country, including the vast amount of material held in storage for the army and navy. When material of this kind is once attacked it is usually worthless for the purposes indicated, and therefore must be replaced with new material. In some cases losses have amounted to from 10 to 50 per cent, and it is estimated that the average losses have been as much as 10 per cent on nearly all sapwood material that has been in storage more than one year.

UTILIZED PRODUCTS.

Powder-post bettles, white ants, and other wood-boring insects.—The finished woodwork in implements, machinery, wagons, furniture, and the inside finish in private and public buildings are often seriously damaged by powder-post beetles, thus requiring increased demands for new material.

Construction timbers and other woodwork in new and old buildings are often so seriously damaged by powder-post beetles, white ants, and other wood-boring insects that the affected material has to be removed and replaced by new, or the entire structure torn down and rebuilt.

Construction timbers in bridges and like structures, railroad ties, telephone and telegraph poles, mine props, fence posts, etc., are sometimes seriously injured by wood-boring larvæ, termites, black ants, carpenter bees, and powder-post beetles, and sometimes reduced in value from 10 to 100 per cent.

PREVENTION OF INSECT INJURIES TO FOREST PRODUCTS.

The problem of artificial control and prevention of insect injuries to forest products offers less difficulties perhaps than that relating to many other branches of the general subject of forest-insect control. In most cases the principle of prevention is the only one to be considered, since the damage is done soon after the insects enter the wood, and therefore it can not be repaired by destroying the enemy.

CRUDE PRODUCTS.

The proper degree of moisture found in the bark and wood of newly felled trees, saw logs, telegraph poles, posts, and like material, cut in the fall and winter and left on the ground or in close piles during a few weeks or months in the spring and summer or during the period when the particular species of injurious insects are flying, are some of the conditions most favorable to attack. The period of danger varies with the kind of timber and the time of the year it is felled. Those felled in late fall and winter will generally remain attractive to ambrosia beetles and adults of round and flat headed borers during March, April, and May. Those felled during the period between April and September may be attacked in a few days after they are felled, but the period of danger from a given species of insect may not extend over more than a few weeks. Thus certain kinds of trees felled during certain seasons are never attacked, while if they are felled at other times and seasons the conditions for attack may be most favorable when the insects are active, and then the wood will be thickly infested and ruined. The presence of bark is absolutely necessary for successful infestation by most of the wood-boring grubs, because the eggs and young stages must occupy the inner and outer portions before the latter can enter the wood. Some ambrosia beetles and timber worms will, however, attack barked logs, especially those in close piles or otherwise shaded or protected from rapid drying. A large percentage of the injury to this class of products can be prevented, as follows:

(1) Provide for as little delay as possible between the felling of the tree and its manufacture into rough products. This is especially necessary with trees felled from April to September in the region north of the Gulf States and from March to November in the latter,

while the late fall and winter cuttings should all be worked up by March or April.

(2) Do not leave the round timbers in the woods or on the skidways during the danger period, or, if this is unavoidable, take every precaution to facilitate the rapid drying of the inner bark by keeping the logs off the ground, in the sun, or in loose piles, or else, if possible, the opposite extreme should be adopted and the logs kept in water.

(3) Remove the bark within a few days after the trees are felled, from poles, posts, and other material which will not be injured by checking or season cracks.

(4) Take advantage of the proper months or seasons in which to fell or girdle different kinds of trees to avoid danger.

Damage to products cut from saplings and left with the bark on can be prevented by transporting the material from the woods soon after it is cut, so that it will not be left in piles or bundles in or near the forest during the season of insect activity. Damage may also be prevented if care is taken not to leave the material stored in one place for several months.

Pinhole damage to stave and shingle bolts cut during a warm season can be prevented by removing the bark from the timber as soon as it is felled and by converting the bolts into the smallest practicable dimensions and piling them in such a manner as to facilitate rapid drying.

Damage to unseasoned handle and wagon stock in the rough can be prevented by taking special precautions to provide against the same favorable conditions for attack as mentioned in connection with round timbers. This is especially necessary with hickory and ash if cut during the winter and spring.

Damage to pulpwood and cordwood can be prevented to a great extent by placing the sticks of wood in triangular or crib piles immediately after they are cut from the trees, especially if the timber is cut during the danger period, or must be held for a few months during the warm season. Peeling or splitting the wood, or both, before it is piled will also provide against damage from insects.

MANUFACTURED PRODUCTS.

UNSEASONED PRODUCTS.

Freshly sawed hardwood lumber placed in close piles during warm, damp weather in the period from July to September, inclusive, presents the most favorable conditions for injury by ambrosia beetles. In all cases it is the moist condition and retarded drying of the lumber which induces attack. Therefore any method which will provide for the rapid drying of the lumber before or after piling will tend to prevent loss. It is important, also, that heavy lumber should, as far as possible, be cut only in the winter and piled so that it will be well dried out before the middle of March.

The damage to lumber and square timber when the bark is left on the edges or sides can be prevented by removing the bark before or immediately after the lumber is sawed, or by sawing and piling the material during the winter, or if sawed at other times it should be piled so that rapid drying will be facilitated.

SEASONED PRODUCTS.

Unfinished seasoned products.—Injury by powder-post beetles to dry hardwood lumber and other material in stacks or storehouses can be prevented as follows:

(1) Have a general inspection of the material in the yards and storehouses at least once a year, preferably during November or February, for the purpose of (*a*) sorting out and destroying or otherwise disposing of any material that shows the slightest evidence of injury, as indicated by the presence of fine powdery boring dust, and (*b*) sorting out and destroying all old and useless sapwood material of any kind that will offer favorable breeding places for the insects.

(2) Prevent the introduction into the lumber yards or storehouses of any infested material, remembering that the insect may be thus distributed to or from all parts of the world.

(3) Adopt a system of classification of all dry or seasoned hardwood stock which will provide for (*a*) the separation of the pure heartwood material from the pure and part sapwood material; (*b*) classification of all kinds of wood most liable to attack, such as hickory, ash, oak; (*c*) the successive utilization or sale of the older material (remembering that material one year old or over is far more liable to injury); (*d*) providing against the accumulation of refuse material in which the insects could breed; and (*e*) treating the best material with linseed oil or kerosene to prevent attack.

Finished seasoned products.—Damage to finished handles, oars, spokes, rims, hubs, wheels, and other unpainted wagon, carriage, machinery, and implement stock in factories, wholesale and retail storehouses, and army and navy stores can be prevented by the adoption of the same general rules as those given under rough products. In addition, damage can be controlled and prevented in the following manner:

Sort out and (*a*) destroy all articles showing the slightest evidence of powder-post injury, or (*b*) treat with kerosene oil such infested and slightly injured articles as may be tested for required strength and found to be of sufficient value for retention, placing the same in quarantine for a sufficient time to determine whether the treatment is successful.

Damage by powder-post insects to many kinds of articles can be prevented and at the same time the material otherwise benefited by treating the sapwood with linseed oil or kerosene, either by immersing it in the oil or by applying the oil with a brush, the application to be made as soon as possible after the articles are finished from recently seasoned, uninjured stock.

PAST AND PRESENT CONDITIONS OF POWDER-POST INJURY.

Up to 1906 there were a great many reports of extensive losses of valuable material from the ravages of powder-post beetles which were seriously affecting all industries involved in the manufacture, sale, and utilization of the classes of hardwood products affected by them. In response to these reports and accompanying appeals to the Department of Agriculture for information on causes and remedies, the problem was thoroughly investigated and specific advice and instructions relating to practical methods of control and prevention have been widely disseminated, both through publications of the Department and special correspondence.

Reports of present conditions from our principal correspondents, together with the less frequent requests for advice, indicate that the disseminated information has been extensively utilized and that it has been worth many millions of dollars toward eliminating the losses and reducing the drain on the limited supply of the kinds of timber required to replenish the damaged and destroyed material.

The army and navy stores of handles, tent poles, wheelbarrows, oars, and many other hardwood articles have suffered severely from powder-post damage, involving an enormous loss, but the carrying out of the information already supplied has evidently contributed greatly toward the elimination of this source of loss to the Government.

TAN BARK.

Damage to hemlock and oak tan bark by the class of insects which in some cases has been so destructive to these products in the past can be easily prevented without cost, as follows:

(1) Utilize the bark within three years from the time it is taken from the trees.

(2) Prevent the accumulation in the yards and store sheds of old bark and waste material in which the insects can breed.

These simple methods have been extensively adopted since their recommendation in correspondence and publications between about 1894 and 1904, and afford one of the most striking examples of the value of expert information on the peculiar habits of insects and of how millions of dollars can be saved without cost through a simple adjustment in methods of utilization.

UTILIZED PRODUCTS.

Damage and loss from insect injuries to timber and other woodwork in structures of various kinds, to telephone and telegraph poles, posts, railroad ties, mine props, etc., can be prevented to a large extent through the adoption of the proper methods of management or of treating the material with preservatives before and after it is utilized.

TIMBERS AND WOODWORK IN STRUCTURES.

Injuries to timbers and woodwork in dwellings, outbuildings, bridges, etc., by powder-post insects can be prevented as follows:

(1) Use nothing but heartwood for the concealed parts most liable to damage.

(2) If it is necessary to use all or part sapwood material, attack can be prevented by treating the sap portions with kerosene, coal tar, creosote, or linseed oil. Facilities for future treatment can be provided wherever the rough or finished woodwork is exposed, as in outbuildings, bridges, etc., if care is taken to expose the sapwood portions.

(3) If the untreated timbers and woodwork in old buildings show evidence of attack, the affected portions should be given a liberal application of kerosene.

Damage by white ants, or termites, can often be prevented in the following ways:

(1) By the use of nothing but sound wood for underpinning and foundation timbers and the removal of decaying timbers from old structures.

(2) By preventing moist conditions of the wood in any part of the structure and especially that in foundation timbers.

(3) By the treatment of timbers necessarily exposed to moist conditions with creosote, zinc chlorid, corrosive sublimate, etc.

(4) If the timbers become infested, further progress of insect damage can be prevented by removing the badly damaged parts and soaking the remainder with kerosene, fumigating with bisulphid of carbon, and by removing any adjacent decaying or other wood in which the insects have been breeding or may breed, such as logs, stumps, etc.

Log cabins and rustic work.—Damage by bark and wood boring insects to the unbarked logs and poles used in rustic cabins, summer houses, fences, etc., can be largely prevented by cutting the material in October and November and utilizing it at once, or by piling it off the ground or under cover in such a manner as to offer the best facilities for the rapid and thorough drying of the inner bark before the middle of March or the 1st of April following. If these necessary precautions are not taken, and there is evidence that insects are at work in the bark and wood, the damage can be checked by injecting bisulphid of carbon through natural or artificial openings in the affected bark, and immediately stopping these and other openings with putty or a similar substance.

Poles, posts, piles, ties, mine props, and similar products.—Insect damage to poles, posts, and similar products can be prevented to a greater or less extent by the preservative treatments which have been tested and recommended by the Forest Service for the prevention of decay. These should be applied before the material is utilized for the purposes intended, or, if it be attacked after it has been utilized, further damage can be checked to a certain extent by the use of the same substances.

It is often of prime importance to prevent injury from wood-boring insects, for the reason that such injuries contribute to more rapid decay. Therefore anything that will prevent insect injury, either before or after the utilization of such products, will contribute to the prevention of premature deterioration and decay.

Approved:
James Wilson,
Secretary of Agriculture.

Washington, D. C., *October 7, 1910.*

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 94, Part I.

L. O. HOWARD, Entomologist and Chief of Bureau.

INSECTS INJURIOUS TO FORESTS AND FOREST PRODUCTS.

DAMAGE TO CHESTNUT TELEPHONE AND TELEGRAPH POLES BY WOOD-BORING INSECTS.

BY

THOMAS E. SNYDER, M. F.,
Agent and Expert.

ISSUED DECEMBER 31, 1910.

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U. S. D. A., B. E. Bul. 94, Part I. F. I. I., December 31, 1910.

INSECTS INJURIOUS TO FORESTS AND FOREST PRODUCTS.

DAMAGE TO CHESTNUT TELEPHONE AND TELEGRAPH POLES BY WOOD-BORING INSECTS.

By Thomas E. Snyder, M. F.,
Agent and Expert.

OBJECT OF PAPER.

It has recently been determined through special investigations conducted principally by the writer that serious damage is being done to the bases of standing chestnut telephone and telegraph poles in certain localities by the grub or larva of a wood-boring beetle, here called the chestnut telephone-pole borer.[a] The character and extent of the damage under different conditions of site in several localities have been determined, and poles treated with various preservative substances have been inspected to compare the efficiency of both chemicals and methods of treatment. These investigations have resulted in the determination of practical methods of preventing injury to poles by wood-boring insects.

HISTORICAL DATA.

The first information of serious damage to standing chestnut poles by wood-boring insects was conveyed in a letter, dated December 15, 1906, from E. O. Leighley, a correspondent of this Bureau, reporting damage to telephone poles in Baltimore, Md., by borers. Mr. A. B. Gahan, assistant entomologist of the Maryland Agricultural Experiment Station, College Park, Md., who investigated the injury to the poles, stated that it was the work of a borer and was located just beneath the surface of the ground. Mr. Gahan brought specimens of the work and the insect to this office. The borers were identified as cerambycid larvæ, and later were determined to be the chestnut telephone-pole borer (*Parandra brunnea* Fab.).

On December 16, 1906, Mr. H. E. Hopkins, division superintendent of a telephone company, stated that the poles in West Virginia were badly injured by borers and that these borers were abundant. On March 8, 1907, he collected larvæ from chestnut telephone poles at Pennsboro, W. Va. These were determined to be the larvæ of the chestnut telephone-pole borer.

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[a] *Parandra brunnea* Fab.; Order Coleoptera, Family Spondylidæ.

The writer on October 3, 1909, inspected some chestnut telegraph poles which had been standing for about twelve years on New York avenue, in Washington, D. C. The poles had been taken down under orders from the city authorities, which necessitated the placing of wires in conduits under ground, and they had been lying in piles for about a month before they were inspected. The chestnut telephone-pole borer had been working in the base of the poles, and white ants, or termites, were associated with them. Twelve out of the 103 poles examined had been damaged, some more seriously than others.

On October 15, 1909, Mr. H. E. Hopkins sent a reply to a request by Dr. A. D. Hopkins for further information regarding insect damage to poles in West Virginia. He stated that in one line built twelve years ago (40 miles long, 36 chestnut poles to the mile, poles 20 to 40 feet long and 5 to 12 inches in diameter at the top) approximately 600 poles had been rotted off at the top of the ground, and inspection showed that 95 per cent of the damage was directly or indirectly due to insects. Other lines in this division were reported to be in about the same condition. It was later determined that most of the insect damage was the work of the chestnut telephone-pole borer.

Dr. A. D. Hopkins states in a recent comprehensive bulletin[a] that "construction timbers in bridges and like structures, railroad ties, telephone and telegraph poles, mine props, fence posts, etc., are sometimes seriously injured by wood-boring larvæ, termites, black ants, carpenter bees, and powder-post beetles, and sometimes reduced in efficiency from 10 to 100 per cent." Thus, while it has been known that almost all classes of forest products that are set in the ground are seriously injured by wood-boring insects, the problem of insect damage to standing poles, posts, and other timbers has never been made the subject of a special investigation.

In May, 1910, this study was assigned to the writer, and, in addition to a study of the insects involved, investigations in cooperation with telephone and telegraph companies have been conducted in the District of Columbia, Maryland, Virginia, Pennsylvania, New Jersey, and New York. Through the courtesy of the Western Union Telegraph Company several telegraph lines were inspected in July and August, 1910, in Virginia, where the poles were being reset or replaced. Here the butts of over 200 poles set under different conditions of site were thoroughly examined for insect damage, and sometimes the

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[a] Insect Depredations in North American Forests. <Bul. 58, Part V, Bureau of Entomology, U. S. Department of Agriculture, p. 67, 1909.

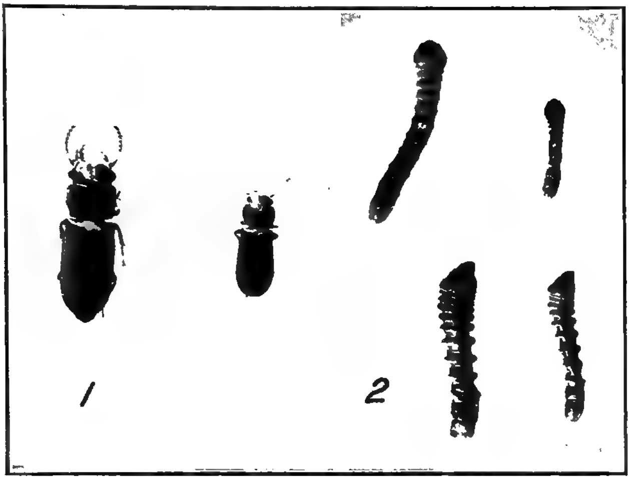

Fig. 1.—The Chestnut Telephone-pole Borer (Parandra brunnea): Male and Female Beetles. Fig. 2.—The Chestnut Telephone-pole Borer: Young Larvæ, Dorsal and Lateral Views. Fig. 1, Slightly Enlarged; Fig. 2, Twice Natural Size. (Original.)

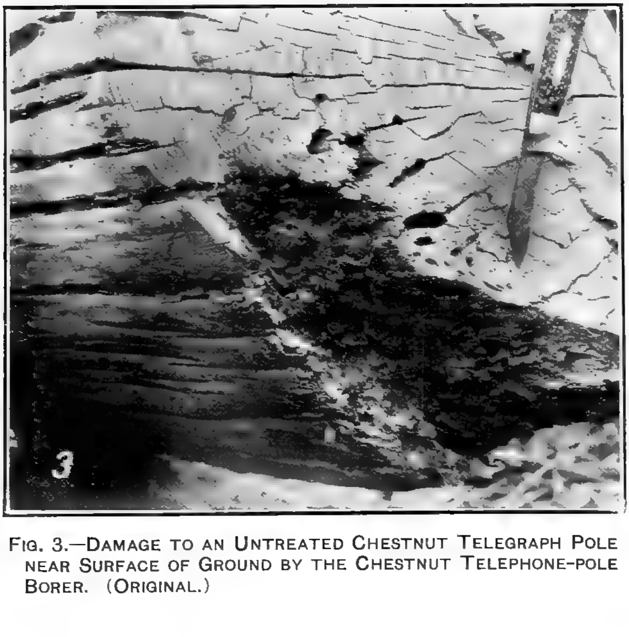

Fig. 3.—Damage to an Untreated Chestnut Telegraph Pole near Surface of Ground by the Chestnut Telephone-pole Borer. (Original.)

entire pole was split open. In one line 10 to 12 years old (approximately 30 chestnut poles per mile, 25 feet long, about 6 inches diameter at the top, 10 inches at the base, and apparently of second quality), between Petersburg and Crewe, Va.—the poles had already been reset once, east of Wilson, Va.—serious damage by the chestnut telephone-pole borer rendered from 15 to 20 per cent of the poles unserviceable. After the present second resetting it was estimated that the poles can not last more than four or five years longer. West of Wilson the poles were naturally in much worse condition, and many were broken off and only held up by the wires on the sounder poles. In another line examined, between Portsmouth and Boykins, Va. (poles 30 feet long and apparently of second quality), serious damage by this borer averaged about 10 or 15 per cent, and between Boykins, Va., and Weldon, N. C., according to a linesman, 50 per cent of the poles are badly decayed near the surface of the ground. Much of this damage, however, is due to fungous heart rot. According to a statement by the foreman of a resetting crew, between Asheville, N. C., and Spartanburg, S. C., hundreds of chestnut poles were badly decayed in the 67 miles of line reset, and were only held up by the wires. The line was 15 years old. There was serious damage by "wood lice" (termites) and also by "white wood worms."

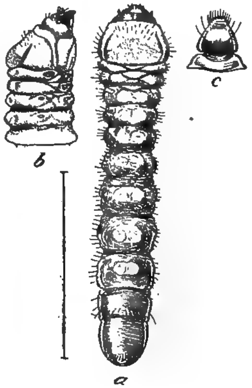

FIG. 1.—The chestnut telephone-pole borer (*Parandra brunnea*): Full-grown larva. (About twice natural size. (Original.)

THE CHESTNUT TELEPHONE-POLE BORER.

(*Parandra brunnea* Fab.)

CHARACTER OF THE INSECT.

The chestnut telephone-pole borer is an elongate, cylindrical, creamy-white, wrinkled, round-headed grub or "wood worm" (fig. 1), which hatches from an egg deposited by an elongate, flattened, shiny, mahogany brown, winged beetle from two-fifths to four-fifths of an inch in length. (Plate I, fig. 1; text fig. 2.) The eggs are probably deposited from August to October in the outer layers of the wood or crevices on the exterior of the pole near the surface of the ground; often the young larvæ enter the heartwood through knots. The young borers (Plate I, fig. 2) hatching therefrom eat out broad shallow galleries running longitudinally in the sapwood, then enter the heartwood, the mines being gradually enlarged as the larvæ develop. As they proceed, the larvæ closely pack the fine excreted boring dust behind them. This débris, which is characteristic of their work, is reddish to dunnish yellow in color and has a claylike consistency. The mines eventually end in a broad chamber, the entrance to which is plugged up by the excelsior-like fibers of wood chiseled out by the strong mandibles of the larva. Here the resting stage (fig. 3), or pupa, is formed, and in this chamber the perfect adult spends considerable time before emerging. Often all stages from very young larvæ only about one-fourth inch long to full-grown larvæ over 1 inch long, pupæ, and adults in all stages to maturity are present in the same pole. Adults have been found flying from July to September. As yet the seasonal history of this borer has not been completely worked out.

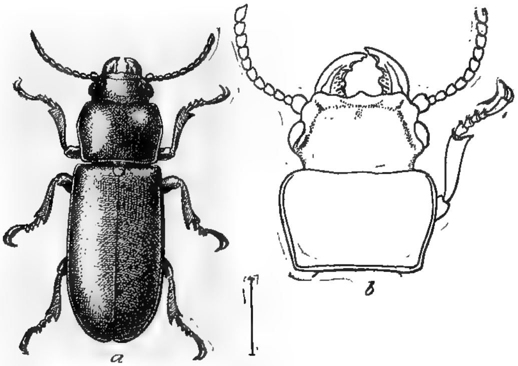

Fig. 2.—The chestnut telephone-pole borer: Female beetle, three and one-half times natural size. Head and pronotum of male beetle. (Original).

DISTRIBUTION.

This insect is very widely distributed, ranging from Ontario, Canada, to Texas, eastward to the Atlantic coast, and westward to Arizona and southern California. It is common throughout the natural range of the chestnut—and in this connection it should be observed that most of the chestnut poles are purchased from local timber-land owners.

CHARACTER OF THE INJURY.

The injury to the poles consists in large mines in the wood near the line of contact of the pole with the ground, necessitating the frequent resetting or even the replacement of the damaged poles. These irregular galleries of the grub (Plate II, fig. 1) run both transversely and longitudinally throughout the heartwood, and are sometimes 7 inches long, but vary with the individuals, which show great differences in size. The borers usually work in the outer layers of the wood at the base of the pole for a distance of from 2 to 3 feet below, and sometimes from 1 to 2 feet above the line of contact of the pole with the surface of the ground. The greatest damage is to that area just below and just above the surface of the ground (Plate I, fig. 3); here the conditions of air and moisture are most favorable. Often the entire butt up to a distance of from 4 to 6 feet and higher, according to the depth of setting, is mined. The numerous galleries, often very close together, completely honeycomb the wood in a zone

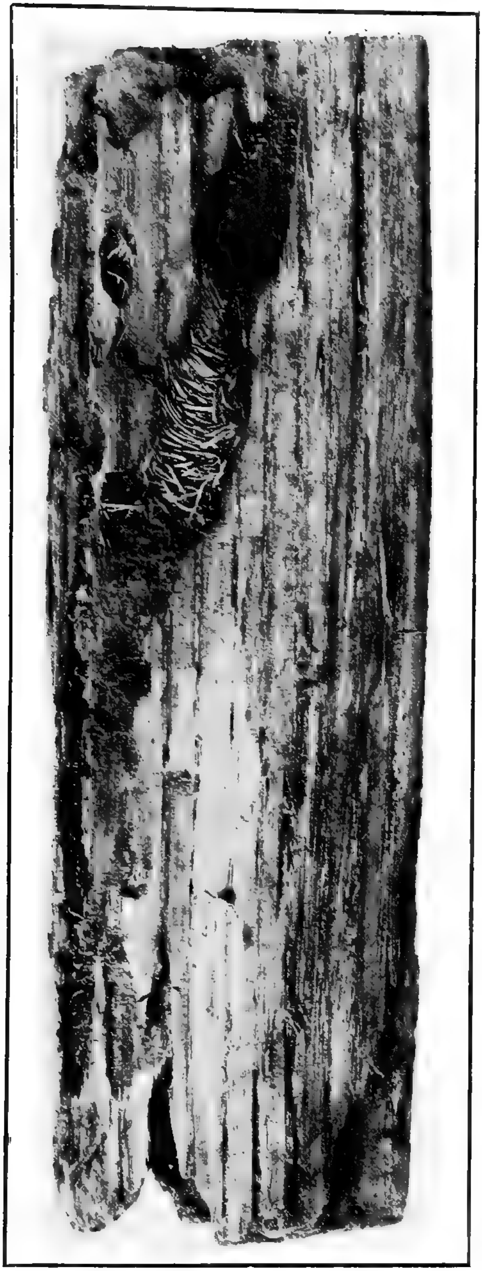

FIG. 1.

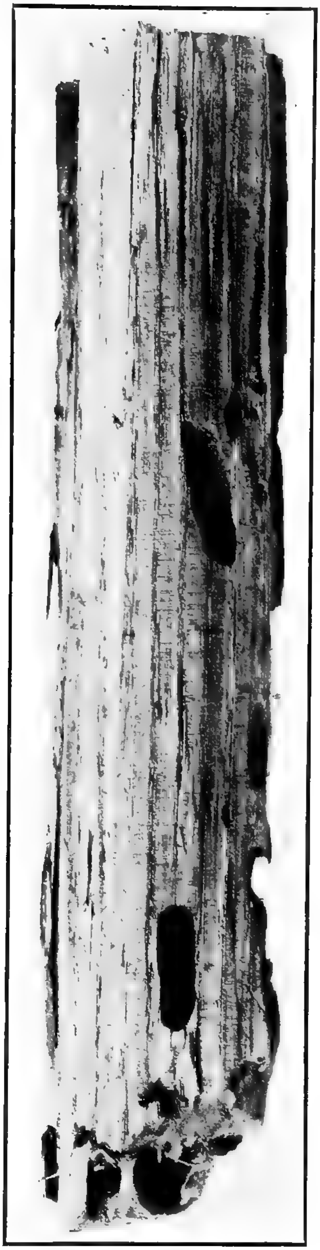

FIG. 2.

WORK OF THE CHESTNUT TELEPHONE-POLE BORER.

Fig. 1.—Gallery of the chestnut telephone-pole borer, showing pupal chamber with the entrance plugged with excelsior-like wood fibers; work near base of pole, below ground. Fig. 2.—Mines of the chestnut telephone-pole borer near surface of ground. Natural size. (Original.)

3 to 4 inches in from the exterior of the poles; this so weakens the poles that they break off close to the surface of the ground. The basal 2 feet is usually sound. Even if the damage is not serious enough to cause the poles to break off under strain, they are likely to go down during any storm, and thus put the wire service out of commission; such damaged poles are a serious menace along the right of way of railroads. The beetle will attack poles that are perfectly sound, but evidently prefers to work where the wood shows signs of incipient decay; it will not work in wood that is "sobby" (wet rot), or in very "doty" (punky) wood. It has not yet been determined just how soon the borers usually enter the poles after they have been set in the ground. However, poles that had been standing only four or five years contained larvæ and adults of this borer in the heartwood, and poles that had been set in the ground for only two years contained young larvæ in the outer layers of the wood.

Poles that appear sound on the exterior may have the entire basal interior riddled, and the work of the borers is not noticed until the poles break off. If merely isolated poles are injured, the poles that are broken off are held up by the wires and can be detected by the fact that they lean over, but if several adjacent poles are affected, especially where there is any unusual strain, that portion of the line is very likely to go down. The presence of the borers in injurious numbers can be determined only by removing the earth from about the base of the pole; the exit holes of the borer are found near the line of contact with the soil. Often large, coarse borings of wood fiber project from the exit holes. Sometimes old dead parent adults are found on the exterior of the poles underground. During August the young adults may be found in shallow depressions on the exterior of poles below the ground surface.

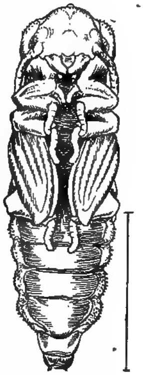

FIG. 3.—The chestnut telephone-pole borer: Pupa. Slightly more than twice natural size. (Original.)

IMPORTANCE OF THE PROBLEM.

The subject of the relation of insects to the rapid decay of chestnut poles has not been thoroughly investigated in the past, but now that the supply is becoming scarcer it is especially important to know what are the various primary causes of the deterioration of these poles, hitherto described under the vague term "decay." Although the chestnut telephone-pole borer has not hitherto been considered an insect of any economic importance, and has been described in entomological literature as only living under bark, principally of pine, or in the decomposing wood of various species of deciduous and coniferous trees, the evidence is abundant that breeding in the bases of chestnut poles is not a newly acquired habit. It has also been determined that this beetle damages many species of living forest, fruit, and shade trees that have been previously injured by fire or other causes, and often leads to the destruction of trees that would otherwise recover from such wounds, and while not normally a primary enemy to trees, may thus become of more than secondary importance.

The damage by the chestnut telephone-pole borer is especially serious in consideration of the fact that in many parts of its range the chestnut is threatened with extinction as a tree species on account of the very severe ravages of the combined attack of an insect [a] and a fungous disease. Further unnecessary drain upon the supply of chestnut timber should be avoided by protecting that already in use and thus prolonging its length of service.

EXTENT OF DAMAGE AND LOSS.

As more than one-fourth of the 3,500,000 round poles exceeding 20 feet in length used annually by telephone, telegraph, and other electric companies are chestnut (Kellogg, 1909),[b] and as this borer has seriously damaged as high as 10 to 40 per cent, varying with conditions of site, of the chestnut poles which have been set in the ground for from ten to twelve years in lines in North Carolina, Virginia, West Virginia, Maryland, and the District of Columbia, it is evident that this insect is an important factor in decreasing the normal length of service of the poles.[c] In lines from twelve to fifteen years old the damage is much greater, and at the end of this number of years of service any line in which poles of this species are set has to be practically renewed. According to a statement in Forest Service Bulletin 78 (Sherfesee, 1909), "approximately 4 per cent, or 5,908,000 feet board measure of the 147,720,000 feet board measure of standing poles annually requiring replacement in the United States, is destroyed by insects." If only chestnut poles be considered, at least 10 per cent of the poles reset or replaced are injured by insects.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR DESTRUCTIVE WORK.

The damage is apparently greatest and the borers are most abundant where the poles are set in high or level dry ground under good conditions of drainage. Such sites are the crests of railroad cuts through low hills, slopes of "fills," and in cultivated or other fields. Where the poles are in wet sites there is usually but little injury by wood-boring insects except to that portion near the surface of the ground. Conditions of drainage are more important than different soil combinations, and the condition of the soil is more important than its composition; *i. e.*, where the soil is hard packed there is apparently less damage than where it is loose. The quality and condition of the poles before setting is a very important factor to consider before arriving at any conclusions as to the relative longevity of poles under various conditions of site. Green (unseasoned) or imperfectly seasoned poles are less durable than those thoroughly seasoned. Poles that are defective [a] before setting, as they very often are (i. e., showing evidence of incipient decay), and poles that have the heartwood mined by the chestnut timber worm,[b] the work of which is very abundant, will, of course, decay much more rapidly than poles that are in an absolutely sound condition. The galleries of the chestnut timber worm afford an entrance to the spores of wood-destroying fungi, and thus greatly accelerate decay. White mycelium compactly filled these galleries throughout many standing poles, thus clearly proving that these mines aid greatly in enabling the fungous heart rot more rapidly and completely to penetrate the entire heartwood of the poles. If the injury by both wood-boring beetles and wood-destroying fungi (between which there is a varying interrelation) be considered, then in several lines from ten to twelve years old in North Carolina, Virginia, and West Virginia at least 50 per cent of the poles are either rendered unserviceable or their length of service is much shortened.

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[a] *Agrilus bilineatus* Web. Yearbook, U. S. Dept. Agr., p. 401, 1909.

[b] See list of publications, p. 11.

[c] The average life of a chestnut pole is eight to ten years (Sherfesee and Weiss, 1909).

ASSOCIATED WOOD-BORING INSECTS.

It is not to be concluded that this wood-boring beetle is the only insect that injures standing chestnut poles. Indeed, the most common injury is by the "wood lice" or white ants.[c] In lines from ten to twelve years old these insects have seriously damaged as high as 15 per cent of the poles, and their work is often present, at least superficially, in as high as 75 per cent of the poles under all conditions of site. However, the damage is usually to the outer layers of the wood, where it is moist or there is incipient decay, and is more superficial and localized than that of the chestnut telephone-pole borer. Nevertheless, white ants often completely honeycomb the sound heartwood of poles, especially at the base. They work both in sound wood, "doty" (dry rot) wood, and "sobby" (wet rot) wood. Sometimes a large channel runs up through the core of the heart and the sides are plastered with clay, forming a hollow tube with several longitudinal galleries. Their work sometimes extends from 2 to 4 feet above the surface of the ground. They leave the outer shell of the wood intact and work up through the longitudinal weathering checks, covering the exterior of the pole with earth to exclude the light. White ants will damage poles that have been set in the ground only two years. Evidently they enter the pole from below the surface of the ground. The habits and characteristics of these peculiar and interesting insects have been thoroughly discussed in Circular No. 50 of this Bureau by Mr. C. L. Marlatt.

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[a] Sometimes this evidence is the old galleries of the destructive two-lined chestnut borer (*Agrilus bilineatus* Web.), showing that the tree must have been dead before it was cut for a pole, and hence is more likely to be defective throughout the interior; in other instances heart rot is clearly present.

[b] *Lymexylon sericeum* Harr.

[c] Identified by Mr. Theodore Pergande of this Bureau as *Termes flavipes* Kollar.

A giant round-headed borer [a] is sometimes found in the poles, usually in association with the chestnut telephone-pole borer. In poles where the wood is sound this borer apparently works as a rule only in the outer layers of the wood, the galleries running longitudinally through the heart below the surface of the ground. In poles where there is decay it will completely honeycomb the heartwood near the surface of the ground.

In several poles where the wood was "doty" a large Scarabæid [b] which has before been found in decayed oak railroad ties was present and caused the poles to break off sooner than they otherwise would. The irregular galleries of the grub completely honeycomb the decayed heartwood near or just below the surface.

A flat-headed borer [c] and wireworms [d] were found in galleries locally in the more or less decayed heartwood of several poles. A large black carpenter ant [e] does some damage to sound poles set in dry ground through woodland. This ant often widens the longitudinal weathering checks and thus accelerates decay. A small black ant [f] was very numerous in many poles, but its work is usually confined to the outer layers of the wood. The work is often throughout "doty" poles. Injury by this ant is not primary, but it also widens weathering checks, enlarges other defects, and induces more rapid decay.

PREVENTION OF THE INJURY.

Doctor Hopkins makes the following statement in a recent bulletin:[g]

> Insect damage to poles, posts, and similar products can be prevented to a greater or less extent by the preservative treatments which have been tested and recommended by the Forest Service for the prevention of decay. These should be applied

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[a] *Prionus* sp.

[b] Identified by Mr. E. A. Schwarz, of this Bureau, as *Polymœchus brevipes* Lec.

[c] Identified by Mr. H. E. Burke, of this Bureau, as *Buprestis rufipes* Oliv.

[d] Species of the family Elateridæ. The large larvæ of *Alaus* sp. were especially injurious.

[e] Identified by Mr. Theodore Pergande as *Camponotus pennsylvanicus* Mayr.

[f] Identified by Mr. Theodore Pergande as *Cremastogaster lineolata* Say.

[g] Insect Depredations in North American Forests. <Bul. 58, Part V, Bur. Ent., U. S. Dept. Agr., p. 84, 1909.

before the material is utilized for the purposes intended, or, if it be attacked after it has been utilized, further damage can be checked to a certain extent by the use of the same substances.

It is often of prime importance to prevent injury from wood-boring insects, for the reason that such injuries contribute to more rapid decay. Therefore anything that will prevent insect injury, either before or after the utilization of such products, will contribute to the prevention of premature deterioration and decay.

Through the courtesy of the American Telephone and Telegraph Company and the Forest Service, about 40 chestnut poles set in a test line near Dover, N. J., were inspected by the writer on July 15, 1910, in company with engineers of the telephone company and Mr. H. F. Weiss, Assistant Director, Forest Products Laboratory, Forest Service, to determine the relative merits of various methods of preventing damage by wood-boring insects to the bases of poles. In this line, which is eight years old, variously treated poles alternated with untreated poles in order that each chemical preservative and method of treatment might be given an absolutely fair test under the same conditions of site. The poles were 30 feet long, 7 inches in diameter at the top, and 33 inches in circumference 6 feet from the base. In this inspection the earth was removed (to a depth of about 1 foot) from the base of the pole, and then the pole was chopped into to determine the rate of decay. This method of inspection for insect damage is not very satisfactory. The various methods experimented with in this test line were brush treatments with a patented carbolineum preservative and spirittine, charring the butt, setting the pole in sand, and setting it in small broken stone. It was found that, although these methods may temporarily check the inroads of wood-boring insects, they will not keep the insects out of the poles. The most serious damage to the poles in this line was by white ants. Other insect damage was by a large black carpenter ant[a] and the larvæ of a round-headed borer.[b]

An inspection was made, between September 6 and 14, 1910, of the bases of over 400 chestnut poles set in a similar test line near Warren, Pa., and Falconer, N. Y. These poles were treated by the creosote "open-tank" method of impregnation, and brush treatments of creosote, wood creosote, creolin, two different carbolineum preservatives, and tar; they had been set in the ground for a period of five years. All these treatments, except the brush treatments with creolin and tar, were efficient in preventing the attacks of wood-boring insects, at least for a five-year period, in this northern climate. There was but little damage by insects to the poles in this test line. The most common injury to the untreated poles was by the large black carpenter ants which widen the longitudinal weathering checks, and hence induce more rapid decay. The work of the chestnut telephone-pole borer was found in several poles, and this beetle was evidently just beginning to attack these poles. There was some damage by a round-headed borer.[a] No white ants or termites were present, and this is evidently too far north for these destructive borers. A report by inspectors of the American Telephone and Telegraph Company and the Forest Service on the remainder of the poles in this test line (between Jamestown and Buffalo, N. Y.) not personally inspected by the writer, showed that these conclusions can be applied to all the poles in the line with the exception that there was superficial injury by small black ants to two poles treated by brush treatments of carbolineum avenarius and to two treated with wood creosote; also, as the inspection progressed, injury by the chestnut telephone-pole borer became more abundant and serious, and the borers seemed to be established in the poles. The poles treated by the creosote "open-tank" method of impregnation and by brush treatments with creosote and with "S. P. F." carbolineum remained uninjured.

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[a] *Camponotus pennsylvanicus* Mayr.

[b] *Prionus* sp.

Methods of treating poles superficially by brushing with various preservatives have proved to be temporarily efficient in keeping wood-boring insects out, if the work is thoroughly done and not only the butt, but also the base, is treated. If the pole is not thoroughly brushed, insects enter through the untreated or imperfectly treated portions, especially through weathering checks and knots. Where the base is left untreated, insects, especially white ants or termites, enter the pole from below ground and, avoiding the treated portions, come right up through the pole.

The few poles of southern yellow pine in a line near Bartley, N. J., inspected on July 15, 1910, which had been impregnated with creosote by the Bethell cylinder-pressure process, 12 pounds of oil to the cubic foot, and had been set in the ground since February, 1903, were apparently absolutely free from signs of decay or damage by wood-boring insects. In another line, running between Norfolk, Va., and Washington, D. C., the few poles (12 years old, of squared—with the sapwood cut away—southern yellow pine) inspected on August 10, 1910, near Portsmouth, Va., which had been impregnated with creosote by the Bethell cylinder-pressure process, were also apparently absolutely sound.

Thus, it is evident that impregnating the poles with creosote by some standard process (either the open-tank or the cylinder-pressure processes) will keep wood-boring insects out and preserve the poles for a much longer period than they would last untreated. In the open-tank method only the area most subject to the attacks of wood-boring insects and deterioration in general (i. e., the basal 8 feet) is treated, while by the cylinder-pressure processes the entire pole is impregnated. Alternating less susceptible juniper (red cedar)[b] poles or pine poles thoroughly impregnated by some standard process in the line with the chestnut poles would be a safeguard in holding up an old line where the damage is found to be serious on resetting.

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[a] *Prionus* sp.

[b] *Juniperus virginiana.*

A list of some available publications on wood preservation is appended.

PUBLICATIONS ON WOOD PRESERVATION AND STATISTICS ON POLES.

1903. Von Schrenk, H.—Seasoning of timber. <Bul. 41, Forest Service, U. S. Dept. Agr.

1906. Grinnell, H.—Prolonging the life of telephone poles. <Yearbook U. S. Dept. Agr. for 1905, Extract No. 395.

1907. Crawford, C. G.—The open-tank method for the treatment of timber. <Cir. 101, Forest Service, U. S. Dept. Agr.

1907. Crawford, C. G.—Brush and tank pole treatments. <Cir. 104, Forest Service, U. S. Dept. Agr.

1907. Grinnell, H.—Seasoning of telephone and telegraph poles. <Cir. 103, Forest Service, U. S. Dept. Agr.

1908. Sherfesee, W. F.—A primer of wood preservation. <Cir. 139, Forest Service, U. S. Dept. Agr.

1908. Weiss, H. F.—Progress in chestnut pole preservation. <Cir. 147, Forest Service, U. S. Dept. Agr.

1909. Sherfesee, W. F.—Wood preservation in the United States. <Bul. 78, Forest Service, U. S. Dept. Agr., pp. 24, 25, Table I.

1909. Sherfesee and Weiss.—Wood preservation. <Rep. Natl. Conserv. Com., vol. 2, p. 663.

1909. Kellogg, R. S.—The timber supply of the United States. <Cir. 166, Forest Service, U. S. Dept. Agr., pp. 20–21.

1910. Willis, C. P.—The preservative treatment of farm timbers. <Farmers' Bul. 387, U. S. Dept. Agr.

Issued December 10, 1910.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—CIRCULAR No. 130.

L. O. HOWARD, Entomologist and Chief of Bureau.

THE OAK PRUNER.

BY

F. H. CHITTENDEN, Sc. D.,

In Charge of Truck Crop and Stored Product Insect Investigations.

65401°—10

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1910

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CIRCULAR No. 130. Issued December 10, 1910.

United States Department of Agriculture,

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

THE OAK PRUNER.[a]

(*Elaphidion villosum* Fab.)

By F. H. CHITTENDEN,

In Charge of Truck Crop and Stored Product Insect Investigations.

INTRODUCTORY.

Many sorts of trees, particularly oak and hickory, grown for shade are often noticed with their limbs severed as if with a knife or saw. Underneath these trees numbers of twigs and small branches strew the ground. The severed limbs are from a few inches to 2 or 3 feet long, and on one occasion a limb was seen that measured 10 feet in length and another that was 1¼ inches in thickness. Young trees are sometimes felled. An examination of one end, sometimes of both ends, of a severed limb will show a smoothly cut surface near the center of which will be seen a more or less oval opening plugged with fine shavings and sawdust (fig. 1, *e, f*).

DESCRIPTIVE.

If one of these limbs be split open at the proper time a soft-bodied larva, resembling that shown in figure 1 at *a*, will be found. This is the larva of the oak pruner. It is nearly cylindrical, soft and fleshy, of a whitish or light yellowish color, and is provided with rudimentary legs (fig. 1, *g*).

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[a] Formerly the species under consideration was known under two names, *Elaphidion villosum* Fab. and *E. parallelum* Newm. The writer, however, has seen an abundance of specimens of what are labeled by both names, and while it may be true that there are two species it is certain that the species which breed in the North from the amputated twigs are identical, since the writer has reared both what are known as *villosum* and *parallelum* from such twigs. That which breeds in the portion remaining on the tree has not been investigated, but it is probably not different.

Horn believed the two species identical and his opinion should not be disputed until the contrary can be proved.

The beetle which produces this larva is slender and cylindrical, dark brown, and clothed with grayish, somewhat mottled pubescence. The antennæ of the female are shorter, those of the male (illustrated at *b*) longer, than the body; the proximal joints are armed with small spines. Each elytron terminates in two small spines and the femora or thighs are unarmed. The length of the body varies from about one-half to three-fourths of an inch.

DISTRIBUTION.

Available records show that the typical oak pruner (*Elaphidion villosum* Fab.) occurs from New England westward to Michigan, and probably farther west, and southward through the District of Columbia and Virginia to North Carolina, while there are specimens in the United States National Museum labeled Texas. It is therefore evident that the species covers the greater portion of the eastern United States, with the possible exception of Georgia and one or two of the Gulf States, from which the typical form has not been seen.

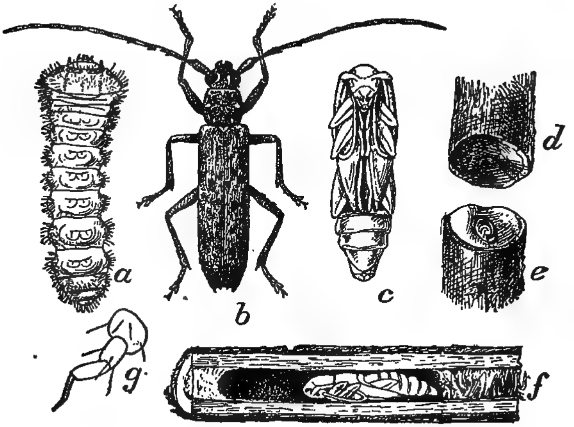

FIG. 1.—The oak pruner (*Elaphidion villosum*): *a*, Larva; *b*, beetle; *c*, pupa; *d*, end of twig cut by larva from tree; *e*, reverse end containing insect; *f*, same from side, split to show pupa within; *g*, leg of larva. *a*, *b*, *c*, About twice natural size; *d*, *e*, *f*, natural size; *g*, greatly enlarged. (Author's illustration.)

FOOD PLANTS AND INJURY.

The list of food plants of this species includes oak, hickory, pecan, chestnut, maple, fir (Abies) (doubtful, recorded by Haldeman), locust, elm, redbud (*Cercis canadensis*), apple, plum, peach, pear, quince, grape, orange, Osage orange (*Maclura aurantiaca*), wistaria, climbing bittersweet (*Celastrus scandens*), black walnut, sweet gum, and hackberry, according to the records of the Forest Insect Investigations of this Bureau. Indeed, this insect or allied species will attack almost every form of deciduous trees, shrubs, and vines with woody stalks. The pruned twigs of various trees and shrubs are of frequent occurrence, and among those which have been noted by the writer in the vicinity of the District of Columbia and in New York are the spicebush (*Lindera benzoin*), sassafras, sumac, English or white walnut, and beech. Since no other species of insect in the regions specified is known to have the same pruning habit, it is practically certain that the species under discussion is the culprit.

Of injuries by this species, it has been reported that in 1886 "peach trees in portions of Michigan were seriously injured. The twigs were cut off so as to nearly destroy some of the trees." In 1892 the extraordinary abundance of this pruner in Pennsylvania, New Jersey, and neighboring States attracted considerable attention. At that time carloads of the branches could be gathered up from the ground throughout the oak forests in Bucks County, Pa. One of the striking features noticeable that year in riding through that part of the country lying between Washington, D. C., and New York City was the unusual amount of injury by Elaphidion on oaks. In some localities every tree had several dead or dying twigs, and the ground beneath was strewn with branches which had been damaged by this species and later broken off by the wind.

In the writer's experience the oak pruner was extremely abundant in years past in the neighborhood of Ithaca, N. Y., and near South Woodstock, Conn., on the shagbark hickory, the severed twigs and branches occurring by the barrelful under a single tree. In one instance a pear orchard at Ithaca, N. Y., had been very extensively pruned. The insect had apparently attacked healthy living twigs and several trees had every appearance of having been killed outright.

A few of the injurious and other occurrences reported to this Bureau during the past decade may be mentioned: Regarding supposed damage to oak, Mr. R. A. Edwards, of Peru, Ind., wrote on March 27, 1901, that he could not observe that the pruner did actual damage beyond cutting off the smaller branches, some of which do not reach the ground, but hang from the limb or lodge upon limbs below and there die. September 5, 1902, Mr. Edmund L. Tyler, of Anniston, Ala., sent a limb of hickory nearly 5 feet in length which had been pruned 3 feet from the end by the oak pruner. The point at which amputation had taken place was an even inch in diameter. April 25, 1903, Mr. Albert M. Boozer, of Columbia, S. C., sent this species, which he thought to be injurious to pecan in that vicinity. It was probably merely concerned in more serious injury due to the pecan twig-girdler (*Oncideres cingulata* Say) and to branch and trunk borers. Mr. E. J. Vann, of Madison, Fla., stated, in a letter dated July 28, 1905, that what he considered this species had almost ruined dwarf chestnuts in that vicinity. Miss Alice S. Hainsworth, of South China, Me., wrote, July 30, 1906, that this species was destroying the beauty of oak trees in that vicinity. The lawn beneath the oak trees was continually strewn with fallen branches. In 1907 report of injury to oak in South Carolina was received. During 1908 the depredations by this species were widespread and general, injury having been reported in Massachusetts, Pennsylvania, Virginia, and Kansas to oak, elm, pear, and wistaria. The year following pecans were attacked in Alabama and Mississippi, and hickory and oak in Illinois. In 1910 the oak pruner attracted widespread attention in the States of New York, Connecticut, and Massachusetts and became the subject of many newspaper notices under the name of the "gun-worm."

LIFE HISTORY.

From present knowledge of this species the following brief account of its life history may be given:

In the northern portion of the upper austral life zone the adult appears in early summer. The mother beetle inserts an egg, usually in one of the smaller twigs of a living tree. The young larva hatching therefrom first attacks the wood under the bark, following the grain of the wood and packing its burrow with its sawdust-like castings. The larva, as it grows, bores toward the base, often consuming the wood entirely around the limb and ejecting its castings through holes which it makes in the bark. Later it follows the axis of the twig, boring through the center and excavating a more or less oval channel, sometimes for a distance of several inches. Dr. Asa Fitch[a] has said that the larva is only about half grown when it severs the limb in which it is working, but it has more probably attained its full growth at this time. He described this operation, recounting at length how, with "consummate skill and seemingly superterrestrial intelligence, he varies his proceedings to meet the circumstances of his situation in each particular case."

From Fitch's account it would seem that he imputed to this insect a reasoning power, which enables it to modify its operations according to conditions and to judge just how far the limb should be cut off to insure its ultimate amputation by the wind without endangering its own safety. Whether guided by reason or by blind instinct, the insect is actually enabled to accomplish this purpose.

After cutting away the wood in such manner that the winds will in time bring the limb to the ground, the contained larva retreats into its burrow and plugs up the severed end with castings. Here it transforms to pupa (fig. 1, *c*, *f*), sometimes late in the autumn and often not until early spring, assuming the adult stage as early as November and appearing abroad in June and throughout the summer until September.

A larva received from South Woodstock, Conn., transformed to pupa May 3 and to adult May 21, having thus passed the pupal stage in eighteen days, the average temperature having been about 74° F.

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[a] FITCH, ASA.—Fifth Report on Insects New York, pp. 797–804, 1859.

Although this species normally completes it transformations in amputated or fallen limbs, it occasionally breeds in limbs that have not been severed. It does not always cut off the twigs in which it lives, and the larva sometimes reverses the order of proceedings and directs its burrow toward the distal end of the branch, which it cuts off at the end of its burrow and remains in the branch attached to the tree.

From the earlier accounts of Fitch and others it would be inferred that the insect requires a single year only for the completion of its life cycle. Dr. John Hamilton,[a] however, has stated that a longer period is required, three years being the usual time, and in individual cases four or more years being consumed. The writer is strongly inclined to believe such exceptionally long periods, even three years, to be the result of undue dryness caused by unnatural indoor conditions.

WHY THE LARVA AMPUTATES A LIMB.

The purpose of the larva in cutting away the wood furnishes an interesting topic for speculation. The object attained is its ultimate fall to the ground.

Peck, who wrote of this species in 1819,[b] thought that the limb, if permitted to remain attached to the tree, would become too dry and that a certain degree of moisture was required for the development of the insect, and that the limb was accordingly partially severed that it might eventually fall, and that then, lying on the ground amid the autumn leaves and beneath the winter's snow, the requisite degree of moisture was insured. In this belief Fitch concurred. Mr. Frederick Clarkson, however, took issue with Fitch, believing that the main object of the larva is to obtain deadwood and to prevent the flow of sap. Here we have two contrary views expressed—one that the object is to obtain moisture, the other to prevent it.

Such an excess of moisture as is obtained on the ground under the melting snow and the pools of water that collect in winter under the infested trees could hardly be a necessity in the life history of any terrestrial animal. The ease with which these insects may be reared from dry twigs indoors is conclusive proof to the contrary. Why they should require more moisture than fifty or a hundred others that could be named that have similar food habits and do not breed exclusively in fallen limbs it would be difficult to explain. Again, that the small flow of sap of oak or hickory could seriously interfere with development would seem unreasonable when we consider that these insects are able to survive the immersion to which they are sometimes subjected for many days together during thaws and rainy spells in winter.

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[a] Hamilton, John.—Canadian Entomologist, vol. 19, pp. 141–145, 1887.

[b] Peck, William D.—Mass. Agr. Repos. and Journ., vol. 5, pp. 307–313, Jan., 1819. (Treated as *Stenocoris putator* Peck. Not seen.)

Another explanation of the limb's amputation occurs to the writer. Those who have reared beetles from hard wood can not have failed to observe that the larva before transforming cuts through the wood until it reaches the bark, which is left untouched and serves to protect the insect from marauding birds or other enemies. When the beetle develops it has only to gnaw its way through this thin layer of bark to effect its exit. There are undoubtedly some wood borers which are provided in the beetle state with mandibles sufficiently powerful to enable them to penetrate hard wood (Monohammus, for example), but the majority, among them Elaphidion, are not thus favored, and would be utterly unable with their weaker boring organs to escape, and would perish in their burrows had they not while larvæ excavated the necessary channel for their exit. These exit channels usually run at an angle to the axis of the wood. Now, in the case of our Elaphidion, which usually lives in a slender limb which it bores longitudinally, there is no room to place a branching, transverse channel; accordingly the larva severs the twig and when it becomes a beetle it cuts its way through the plug of castings.

As to Fitch's claim that the larva varies its operations to suit the different sizes of limbs, the average infested twig is of about the thickness of one's finger, and it is probable that the larva commences proceedings late in the season with the approach of cold weather when it is about full grown and ready for hibernation. To cut off the limb is a labor of some magnitude for so small a creature and may require several days for completion. It has a limited amount of energy, being now toward the end of its active existence as a borer, and the cooler weather serves to repress this energy, which is sufficient for cutting away all the wood in a small twig, but is inadequate for a larger one. The wood of a large branch is harder, and the insect ceases work, perhaps from exhaustion or from cold, or because its instinct impels it to cut a certain amount, and when that is accomplished to cease, its work being ended. At the close of his narrative Fitch says, in spite of a previous assertion that the insect never miscalculates, that—

> in at least three-fourths of the fallen limbs no worm is to be found; and an examination of them shows that the insect perished at the time the limb was severed and before it had excavated any burrow upward in its center, no perforation being present except that leading into the lateral twig. It is probable that in many instances the limb broke when the insect was in the act of gnawing it asunder, either from its own weight or from a wind arising whilst the work was in progress.

NATURAL ENEMIES.

As might be inferred from its manner of life, this insect enjoys as nearly perfect exemption from predaceous or parasitic attack as falls to the lot of most wood borers. Fitch, however, has stated that some of our insect-eating birds destroy the larvæ, and the writer has reared the parasite *Bracon eurygaster* Brullé from twigs inhabited by the species.

Among natural enemies of the oak pruner, Mr. F. H. Mosher[a] records the downy woodpecker (*Dryobates pubescens*), the blue jay (*Cyanocitta cristata*), and the black-capped chickadee (*Penthestes atricapillus*). Mr. W. L. McAtee, of the Bureau of Biological Survey, states that a species of Elaphidion is preyed upon by the downy woodpecker and by the great-crested flycatcher (*Myiarchus crinitus*). Mr. A. H. Kirkland[a] records having found a spider (*Theridium tepidariorum* C. Koch) feeding upon the mature insects.

REMEDIES.

The pruning process is not always in itself especially injurious, since when the pruner occurs in only moderate numbers the vitality of the tree is not impaired. The ultimate effects, however, are likely to be more serious. The fallen twigs serve as a breeding place for hosts of other wood borers, many of which are injurious to shade trees and to standing timber. Some of these do not hesitate, in default of an abundance of dead or injured wood, to attack and damage apparently healthy living trees.

In case this species becomes injuriously abundant, it may be readily controlled by gathering the pruned twigs and burning them. This should be done from time to time, as otherwise they accumulate and make the lawn unsightly. To make this remedy of any value, the cooperation of neighbors is desirable. The work should be as thorough as possible. If the twigs are gathered in numbers during one season, the chances are that the insects will not be nearly so abundant the year following.

Approved:
James Wilson,
Secretary of Agriculture.

Washington, D. C., *October 14, 1910.*

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[a] Forty-fifth Annual Rep. Sec. Mass. State Board Agr. for 1897 (1898), p. 244.

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NOVEMBER, 1910 BULLETIN 286

CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION OF
THE COLLEGE OF AGRICULTURE
Department of Entomology (Extension Work)

THE SNOW-WHITE LINDEN MOTH

By GLENN W. HERRICK

ITHACA, N. Y.
PUBLISHED BY THE UNIVERSITY

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The regular bulletins of the Station are sent free to persons residing in New York State who request them.

THE SNOW-WHITE LINDEN MOTH

Ennomos subsignarius Hübn.

Order, Lepidoptera; superfamily, Geometrina

A half century ago the snow-white linden moth was a conspicuous insect in some of our Eastern cities and its caterpillars were very abundant and exceedingly injurious to shade-trees. From 1857 to 1870 the shade-trees of Brooklyn, N. Y., and Philadelphia, Pa., were annually subjected to defoliation by this insect. To check its increase, the English sparrow was introduced from Europe, and so well did this bird do its work that for nearly a half century we have heard almost nothing about this insect as a shade-tree pest. During this time there has been an occasional reference to it as a forest-tree despoiler, but it was not until 1907 that it again appeared as a serious pest, in New York State at least. During that year it seriously injured forests in the Catskills and the Adirondacks. In 1908 and 1909 it was again very abundant and seriously injurious, and now in 1910 it promises to be as prevalent as ever. During the last two years, in rearing large numbers of the moths the writer has been able to find but one single specimen of a parasite. It may be that the absence of parasites is the main reason for the great abundance of this insect. At any rate, we must conclude that the environments, climatic conditions, and other factors have been especially favorable for this insect during the past four or five years. Just how long it will continue in its present abundance, how widely it will spread, and whether it will eventually become a pest to our fruit-trees and ornamental plants, are questions the answers to which we shall await with much interest and considerable anxiety.

THE NAME

This insect has masqueraded under several names during its career with the scientists. It was first named in 1806 by Hübner, who called it *Eudalimia subsignaria*. About a half century afterward, T. W. Harris, in a paper in Hovey's Magazine of Horticulture, says, "This species not having been scientifically described or named before may be called *Geometra niveosericearia*, the snow-white silky Geometer." In 1857, Guenee placed it in the genus *Ennomos*. Four years later, Mr. J. B. Jones, in a communication to the Entomological Society of Philadelphia, referred to it as *Geometra niveosericearia*, and also gave it the common name of "measure-worm," although it had no more claim to this particular appellation than many other caterpillars of the same family. Packard, in a discussion of the insect in 1869, gave it Guenee's old name again, *Ennomos subsignaria*, but in a subsequent and more extended discussion in 1876 changed it to an entirely new genus, *Eugonia subsignaria*. Finally, in 1891, Dr. J. B. Smith, in his "List of Lepidoptera of Boreal America," listed it under the name, *Ennomos subsignarius*, and under this it has since remained.

Dr. Lintner, in 1882, first proposed the common name of snow-white linden moth because of its snow-white color and its chief depredations, as he then supposed, on the linden tree. It was soon found however, that it attacked other trees quite as seriously and extensively as the linden, but since the name was as appropriate as any, it has clung to the insect to the present day.

HISTORY OF THE SNOW-WHITE LINDEN MOTH

Early history.—The snow-white linden moth was first described in 1806 and has been known to science ever since; but it was not until about 1860 that it began to attract attention in this country as a serious pest. In 1855, T. W. Harris discusses the abundance of the larvae in the city of Brooklyn and says that a correspondent writes that the "worms" were first seen in the city "ten years ago," since which time they have appeared at the regular season every year. In 1861, Dr. J. B. Jones wrote a report on the measure worms which infest the trees of Brooklyn, with suggestions for treatment. In the same year, the citizens of Brooklyn became so excited over the increase of this measuring worm that the Common Council seriously discussed a resolution compelling the destruction of all linden trees on the streets of the city. In a subsequent examination, however, the caterpillars were found on so many other varieties of shade-trees that it was seen that no permanent good could be accomplished by the destruction of the linden trees and the resolution was laid on the table indefinitely. In 1881, Mr. Grote wrote that, when he lived in Brooklyn in 1857, this measuring worm was so abundant "that the horse-chestnuts, elms, and maples, the latter especially, became completely defoliated, and the brown measuring worms used to hang down and cover the sidewalks ultimately to the great discomfort of the passers by." It is said that this condition continued until the introduction of the English sparrow, which is considered to have destroyed the caterpillars and held the pest in check.

In 1880 the pest was discovered in Georgia. Professor Comstock reported the caterpillars as destroying forests of hickory and chestnut and doing much damage to fruit-trees. Since that time we have heard mention of the insect only now and then until within the last three years.

Later history.—On July 6th, 1909, we received from a correspondent at Cooks Falls, N. Y., the following letter concerning this pest: "Last year there appeared in this community a worm somewhat similar to the common apple tree worm and known locally as the 'beech' worm from its habit of eating the leaves of the beech tree. We thought it would die out over winter, but have been disappointed in this hope. It is again eating the foliage of the same trees it stripped last year and is threatening large tracts of very valuable timber land. While it appears to prefer the beech leaves it quite often attacks maple, birch, etc. As our interests in timber land are considerable, we write to enlist your aid in determining what species of worm this is, and how its ravages can be stopped." In response to this appeal, the writer made a personal inspection of the infested area and found a fine forest of beech, maple, and other wood, over five hundred acres in extent, literally stripped of leaves by the larvae of this moth. The owner said that they were so numerous that the dropping of the excrement sounded like rain pattering on the leaves. The undergrowth was almost as bare as it would be in winter. The young beeches had suffered more severely than any other trees and most of them were entirely bare of leaves. Hundreds of empty pupal cases, partly rolled-up in eaten leaves, were hanging to the trees. The caterpillars had covered a certain area on the top of this particular mountain and part way down one side. The line limiting their injuries was clear and evident to the eye long before we reached the actual area. For two successive years this forest had been denuded and the larvae were just as abundant this year (1910) as ever.

On July 9, 1909, a correspondent at Arena, N. Y., about twenty miles from Cooks Falls, wrote that the caterpillars "are working mostly on beech, ash, birch, and maple. In fact, nothing comes amiss to them. In driving through the town of Hardenburgh, Ulster Co., I noticed the trees were literally stripped of their foliage and a fence running in the woods was so loaded with them (caterpillars) you could not see the rails. They hang by webs on the trees, and looking through the forest appears like looking through smoke or a fog." This same correspondent wrote on May 16th, 1910, nearly a year later, that the trees were again "literally covered with the very small caterpillars and that if nothing can be done to check them the Catskills are doomed." The pest is evidently widely distributed, for there are reports of its injuries in Ulster Co., Sullivan Co., and also in the forests of the Adirondacks.

In his report for 1908, Dr. Felt says that the Forester, E. S. Woodruff, reports the beeches on a tract of over two square miles as completely defoliated. The caterpillars seem to attack the beeches first, but finally spread to the birches and maples. (Fig. 54).

One of the most remarkable phases of this pest were the flights of great swarms of the snow-white moths in cities and towns throughout the eastern part of the State and in New Jersey. In New York City the effect was compared to a snowstorm in mid-summer. Myriads of the moths fluttered about the electric lights. Dr. John B. Smith says that on the evening of July 17th, Newark, Elizabeth, and Paterson, N. J., had the same experience. On the morning after the flight, however, nothing remained except great numbers of snow-white wings without bodies, showing the work of the English sparrow, and probably of other birds and destroyers. These flights are remarkable since the presence of the caterpillars had not previously been noticed in these towns and cities. It seems probable that the moths must have flown long distances from the feeding places of the caterpillars in the forests. During the latter part of July, 1909, Ithaca and several other cities

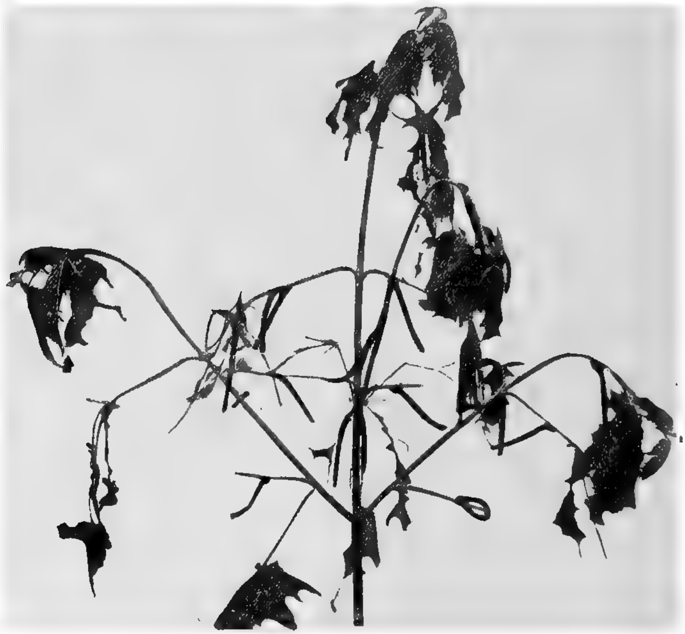

FIG. 54.—*Caterpillars of the snow-white linden moth on maple*

in the central part of the State experienced similar flights of myriads of the spruce bud moths. These moths could not have bred in such numbers on ornamental spruces in the near vicinity of the towns invaded but must have come from some forested areas, perhaps at long distances from the towns invaded. Thus we have an undoubted second instance of a moth which has certainly flown long distances from the feeding places of its larvae.

THE DANGER AS A FRUIT PEST

The first reference to this insect as a fruit pest that the writer finds is by Thomas in his Second Illinois Report, in which he says that he twice found the larvae on apple trees, though not in large numbers, and had reared them to the perfect insect on the leaves of this tree. In 1880, Comstock, quoting a correspondent, says that the larvae were damaging fruit-trees in Georgia. In 1882, Dodge, in the Canadian Entomologist, quoting from the same correspondent in Georgia, writes that the "apple trees in June last were as destitute of leaves as in midwinter, the fruit growing to the size of marbles and falling off."

In 1904, Garman writes of this insect as an important pest of the apple tree in Muhlenberg Co., Kentucky. It was especially injurious in 1903 but not so serious in 1904, due probably to the work of parasites. Again, in 1908, Garman treats of this pest as a serious one on apple trees and says that this species "is sometimes very common locally and may defoliate whole orchards at times." In his 23rd Report, Felt says very significantly, "It would not be surprising if a number of outbreaks, hitherto attributed to our more common canker worms, were in reality the work of this species."

It is quite evident that we have in this insect a possible future fruit-tree pest of considerable importance. It apparently used to be confined to the shade-trees of our cities but it has now almost entirely deserted these for our forest-trees. It would not be at all surprising in view of the history of this insect if the future should see it migrating from the forest-trees to our fruit-trees and becoming a serious pest.

DISTRIBUTION

Evidently this insect is widely distributed over the Middle and Eastern United States, and it occurs in Canada. It has been recorded from Nova Scotia to Georgia and westward through Michigan, Kentucky, Iowa and Colorado. In New York State, the moths have been reported from Delaware, Ulster, Sullivan, Rensselaer, Albany, Columbia, Saratoga, Schenectady, Herkimer, Fulton and Oneida Counties, and from the northeastern part of the State in the Adirondacks.

FOOD PLANTS

The larvae infest a great variety of forest-trees, apparently somewhat preferring beech and maple. They have been found on elm, linden, chestnut, hickory, ash, apple, birch, and others.

THE LIFE HISTORY AND HABITS OF THE INSECT

This insect requires nearly a year to pass through its life history. It is said that in Georgia the eggs were laid on the leaves as though there might be a second brood or generation in a season. It would seem from a study of the insect in New York that this must have been due to the carelessness of the female moths and can hardly be taken as an evidence of a second brood. At any rate, there is only one brood in New York State each year; and this is fortunate. If this pest could pass through its life history and produce a generation every two or three months, our forests would surely be doomed to destruction.

The eggs of the female moth are laid on the under sides of the branches —as often on the upper branches of the smaller trees, at least, as on the lower. In a rather hasty search, the writer found the eggs laid on the beech only. However, a correspondent at Arena, N. Y., has sent many eggs deposited on maple. The eggs are always deposited at an oblique angle to the surface of the bark and lean against each other like a pile of leaning bricks. They are laid in masses of 20 to 100 or even more, and are stuck so securely to the branch that in 1909 the writer found still adhering to the trees the empty shells of quite as many old egg masses of 1908 as there were new ones of 1909. The eggs are deposited on the branches in the latter part of June and first part of July, and remain unaffected by snow, rain, or extremes of temperature until the following April and May, nearly a year after deposition.

The eggs are about one twenty-fifth of an inch in length, barrel shaped, often more or less flattened on the sides, light olive when first deposited but later becoming darker in color, with a conspicuous ring at the free extremity. They occur in irregular masses, long and narrow if the branch is small but spread out if the surface is large (Fig. 55).

Eggs brought from Cooks Falls in August, 1909, were placed outdoors under natural conditions and began to hatch May 2nd, 1910. Eggs sent from Cooks Falls on May 11th, 1910, had not hatched, and the writer found that the caterpillars on the mountain at Cooks Falls had appeared two to three weeks later than at Ithaca or at Arena, N. Y., the difference probably being due to the higher altitude and lower temperature. Eggs at Arena, N. Y., brought into the house in

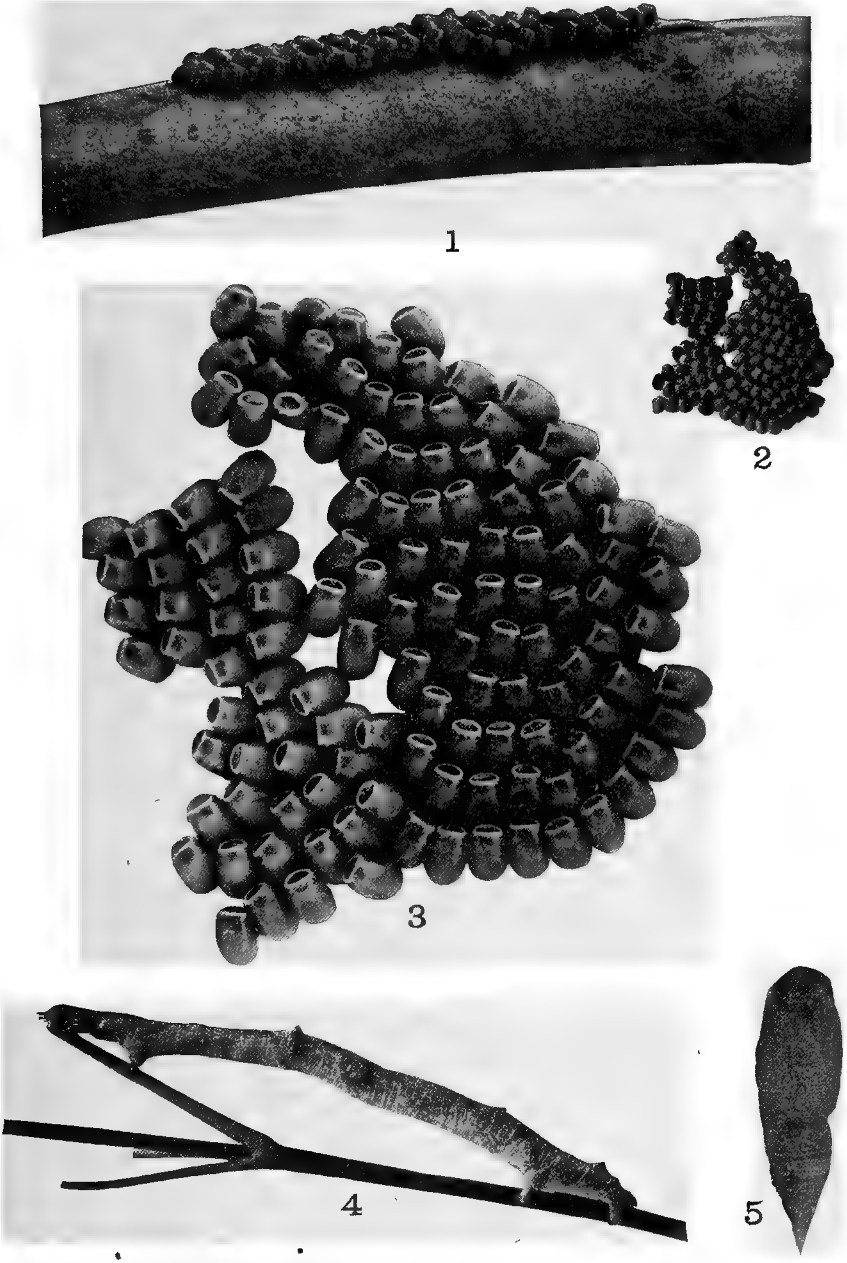

FIG. 55.— *The snow-white linden moth:* 1, *egg mass, side view;* 2, *eggs enlarged;* 3, *eggs much enlarged;* 4, *larva enlarged;* 5, *pupa enlarged*

February, moistened and placed by the stove, hatched and the caterpillars, which were fed on leaves of Abutilon, apparently throve finely but were not reared to maturity. Other eggs from Arena placed outdoors under natural conditions hatched at Ithaca as early as April 23rd.

The number of eggs that may be deposited on a single tree is very great. The number in six average clusters ran as follows: 93, 21, 44, 40, 89, and 67, respectively. Many clusters contain more eggs than the highest of the foregoing. Scores of such egg clusters exist on many of the trees in the infested area. Messrs. Graef and Weibe say that they removed at least 60,000 eggs from one small maple tree in Brooklyn.

It is probably right to say that the eggs of this moth begin to hatch in the latter half of April, and in high altitudes probably not much before the middle of May. When a caterpillar first emerges from the egg it is only about one-tenth of an inch in length and its general color is green. The head, last abdominal segment, and sides of the body are light green while the back is a darker green. In general, when the larva is viewed from above, the two ends of the body appear light green in color with the part between a darker olive green.

The young larvae begin at once to eat the green tender leaves. On May 3d, the writer placed six caterpillars, just out of the egg, on fresh tender maple leaves, each caterpillar on a leaf by itself, to watch its habits of eating. By the morning of May 5th each one had eaten holes through its leaf, varying from pinholes up to good sized shot holes. In one leaf eighteen such holes had been eaten, which shows something of the voracity of the tiny larvae. Observers who have had the opportunity to watch these larvae in the forest say that at first they climb to the top of the tree and to the ends of the branches where the leaves are presumably younger and more tender. As they grow they gradually ravage the entire tree.

The caterpillars vary considerably in color and markings. In general, after the first molt they become dark reddish brown, in many cases almost black, with the head and last abdominal segment red or reddish brown and quite conspicuous. The larvae resemble the twigs of the tree on which they are feeding, and like other "measuring worms" have the habit of holding themselves erect and motionless like a broken twig. The six larvae reared on separate maple leaves and receiving an abundance of food were without exception of a beautiful pale rose color with three distinct tubercles on the abdomen, as shown in Figs. 54, 55. Many of the caterpillars received from the infested forest trees were of a light green color throughout and in marked contrast with the darker ones. Full grown caterpillars that have had all the food they want become a little over two inches in length, but when they are crowded and the food supply limited they are often less than two inches long. During their growth the larvae molt five times or even six times. Graef and Weibe record only three molts.

The caterpillars of this moth have the three pairs of true legs attached to the thorax, but only the last two pairs of abdominal legs are present, thus leaving the middle of the body unsupported. Hence, instead of walking like many other caterpillars do, they move with a looping gait and have been called "looping" caterpillars or "measuring worms." Moreover, they have the habit of spinning a silken thread and letting themselves down by it from the branches when the tree is suddenly struck or jarred. Frequently they drop half way down to the ground and remain quietly suspended in the air for a few moments, after which they ascend to the branches above. It is said that during their great abundance on the shade-trees in Brooklyn in the sixties much annoyance was caused by this habit of dangling in the faces of pedestrians. The following remarks of a committee from the Brooklyn Horticultural Society anent this phase of the insect are interesting: "It would seem to be entirely unnecessary for the committee to urge upon those who have been constrained to traverse our streets in the latter part of June and the early part of July, the great importance—they might almost say the necessity—of devising and accomplishing *some* plan for removing the worms which dangle before their faces, are dropped upon their clothing, or are crushed by their feet at every step. Certainly no gentleman, no lady, can need to be convinced that carrying these worms from house to house, brushing them out of the face and hair, or stopping at the corners to pick them off with the fingers—at the risk of crushing them in the experiment—is not a part of the privilege which one looks for in becoming a resident of a city like this."

Six caterpillars that emerged from eggs May 3rd began spinning their cocoons May 30, July 1, 2, 3, 6 and 7, respectively, and changed to pupae about three days after commencing the cocoons. It should be understood that these larvae were under exceptionally favorable surroundings so far as food was concerned. The cocoons are very flimsy affairs and usually are made by turning over the edge of a ragged leaf and lining the inside with a thin net-like layer of silk (Fig. 56). Graef and Weibe say that the insects pupate on the trunks and branches of trees, on fences, railings, lamp-posts, or almost anything they can reach.

The pupa is about five-eighths of an inch long, sometimes more, sometimes less. It is blunt and rounded at the anterior end but strongly pointed at the posterior extremity and terminates with about six small,

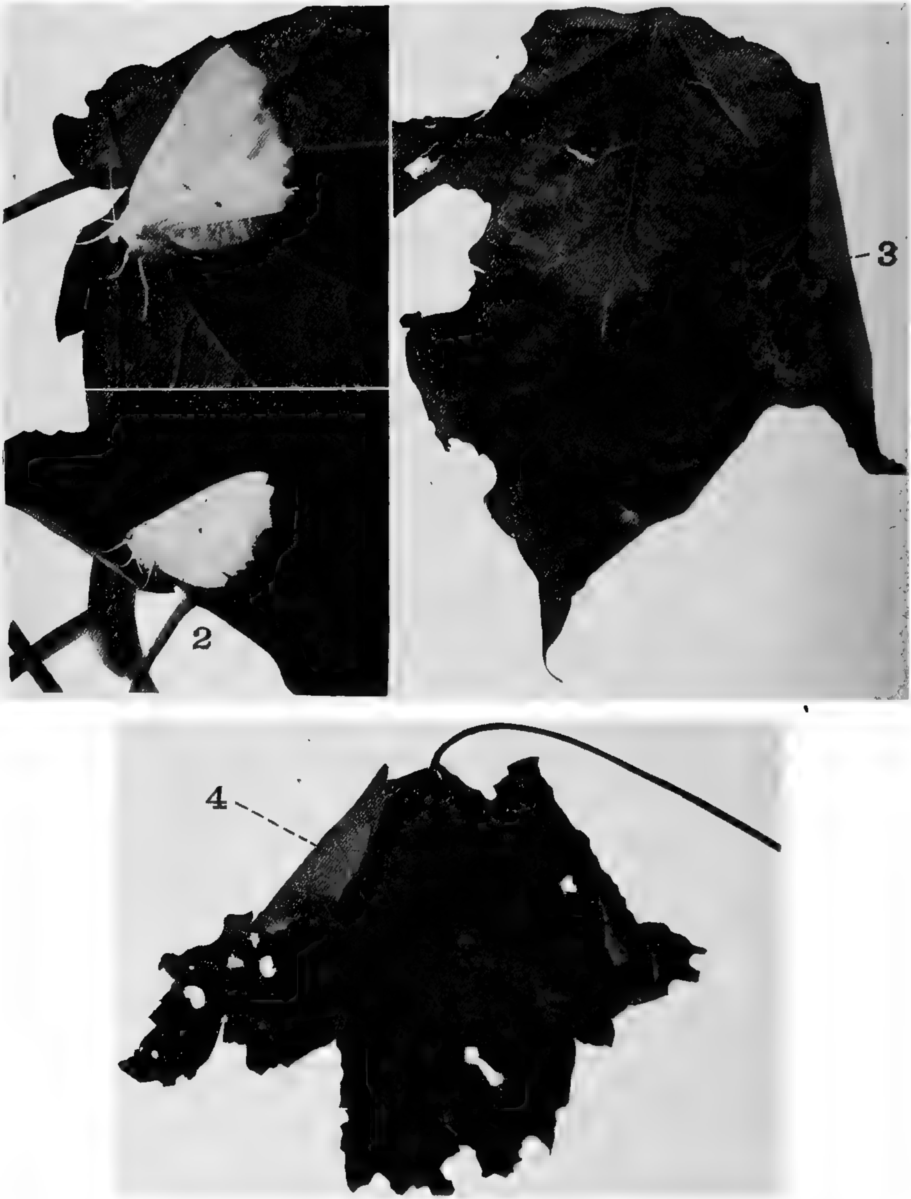

FIG. 56.—*The snow-white linden moth:* 2, *moths from nature;* 3, *lace-like cocoon;* 4, *pupa under the rolled edge of a leaf*

chitinous hooks that securely fasten the pupa to the network of threads lining the cocoon. The pupa is of a pale brown color flecked with numerous black dots which in some places run together. The six pupae, under observation, occupied 13 to 16 days for their transformations to adults.

The moths are pure white, and the females are somewhat larger than the males and have thread-like antennae, while the males possess feather-like antennae. The front wings of the male and the female are angulated, those of the female more prominently. Packard says that the hind wings of the male are entire. In a long series of bred specimens, many males show notched hind wings while some are entire in outline. The hind wings of the female are noticeably and quite regularly notched. (Fig. 57).

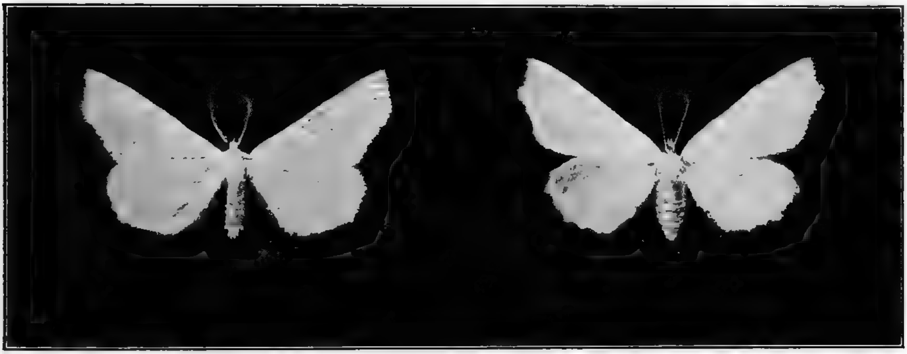

FIG. 57.—*Male moth at left, female at right*

From the eggs brought to Ithaca from Arena and Cooks Falls we find the moths appearing from June 16 to July 1st. From caterpillars obtained from Cooks Falls in 1909 we find the moths appearing July 18 to July 25th. At Arena, N. Y., in 1909, the larvae were found pupating about July 1st and the moths appeared about the middle of July. It would seem, then, that the adult moths appear from the middle of June to the last of July, depending upon the season, altitude, and other factors. The eggs are deposited within a few days after the moths emerge, thus completing the life cycle.

NATURAL ENEMIES

What the natural checks of this insect are we are unable to say at present. It is evident that some unfavorable conditions have operated to hold it in check for the last fifty years, and it is equally evident that for the past three or four years these forces have been partly or wholly inoperative.

The testimony regarding the activity of the English sparrow in exterminating this pest in cities seems to show rather conclusively that this much-disliked bird did actually bring about the destruction of this insect. Nearly every writer on the snow-white linden moth makes acknowledgment to the sparrow and declares that the cities owe their freedom from this insect to that bird. We take pleasure in again calling attention to this little-known meritorious work of the English sparrow.

Mr. William H. Broadwell in describing the visitation of the snow-white linden moths at Newark, N. J., on the night of July 17th, 1908, as "a July blizzard," has the following to say regarding the work of the sparrows in destroying this insect: "Early the following morning, under the lamps, the wings were on the ground as thick as apple blossoms after a storm, showing that the sparrows had not forgotten why they were brought over to this country some forty years ago." Mr. Grote, in a paper from which we have already quoted, after discussing the great abundance of the measure worms in Brooklyn, says further, "The advent of the English sparrow changed all this. The naked brown larvae of *subsignaria* disappeared before them."

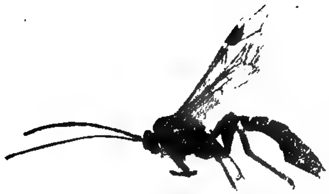

FIG. 58.—*A parasite (Pimpla conquisitor) of the snow-white linden moth*

In 1880, Mr. G. H. French of Carbondale, Ill., bred five males and seven females of a minute Hymenopterous parasite, *Macrocentus iridescens*, from two caterpillars, which he took to be *Ennomos subsignaria*, found on an elm tree. We have not been fortunate enough to find this parasite present in any of the caterpillars reared by us. We have, however, bred one single specimen of a common parasite, *Pimpla conquisitor* (Fig. 58), from the pupae of the snow-white linden moth. Since only the one specimen has been obtained from the scores of pupae we have had, it will be seen that this parasite is not abundant enough yet to be of any great service as a check. Mr. Harris says that *Chalcis ovata*, a small parasite, has also been reared from the pupae.

It may well be that the great and wanton destruction of birds is one cause of the abnormal abundance of this insect. If one bird is so efficient in the control of this pest, as the evidence shows it to have been, then why may we not legitimately expect a great deal of our native birds in this respect? Undoubtedly one of the most efficient and feasible means for the control of this insect in our forests will be the better protection of our native birds.

METHODS OF CONTROL

In the control of this pest in shade-trees, spraying with arsenate of lead, 3 pounds to 50 gallons of water, would probably be very effective. If it ever becomes injurious to apple trees in this State, the same method of control would have to be followed. The trees should be sprayed early while the caterpillars are small, as the poison will be much more effective then.

As we have already noted, the caterpillars have the habit of suddenly dropping to the ground in great numbers when the trees are jarred. On small trees, hundreds of the caterpillars may be jarred on to sheets and then destroyed. Unfortunately, the young larvae are not so susceptible to this kind of treatment, and if one waits until they become large much of the damage will already have been done.

The masses of eggs are very conspicuous objects and could easily be found on the branches and scraped off. In the case of small trees much good could be accomplished in this manner. On large trees it would be more difficult to collect the eggs.

In forests there seems no practicable way of controlling this pest. In case of the particular forest area mentioned at Cooks Falls, the wood is being grown for the manufacture of certain wood chemicals. In this instance it may be best to cut off the present growth of timber and use it for the distillation products before it dies as a result of the annual defoliation to which it has been subject for the past two years.

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PARASITES

OF THE

GYPSY AND BROWN-TAIL MOTHS

INTRODUCED INTO

MASSACHUSETTS.

WHERE THEY COME FROM.
WHAT THEY ARE DOING.
A GENERAL SURVEY OF THE WORK.

BY W. F. FISKE,
Agent and Expert, Bureau of Entomology, U. S. Department of Agriculture.
UNDER THE DIRECTION OF
F. W. RANE, STATE FORESTER.

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INTRODUCTORY.

This bulletin is published by the State Forester in order that any of our citizens interested may have a definite and comprehensive knowledge of the work that the State of Massachusetts is doing in importing parasites and predatory enemies of the gypsy and brown-tail moths.

I am sure this bulletin will meet a cordial reception by many of our people, as it explains the various points often so difficult to propound in the short time at one's command.

The time has come when we should have a better practical working knowledge of the future care of our trees. We must look upon these moth depredations and their ultimate control in a rational manner. When forest fires are burning, we do not hesitate to put them out, realizing their great destructiveness if allowed to run at will. The enormous damage that these moths have done in eastern Massachusetts is appreciated only by those who have lived in the infested districts. We propose to have many strings to our bow in fighting these moths. The work of introducing parasites, thought by scientists to be of great promise, was begun in 1905 and has been vigorously pursued ever since. It has not been by any means an easy matter to secure them in sufficient quantities, and get them established in this country in large enough numbers, to secure the desired results. Each year, however, has improved on the past, until at present very effective work is in progress. More material was secured last year than during the whole time previously, and the coming year is even more promising. The gypsy moth itself was here a number of years before it became sufficiently abundant to be considered a pest. If it took the gypsy moth many years to get established, with all favorable conditions apparently at its bidding, we must not get over-impatient awaiting the results which are hoped for in the introduction of its natural enemies. This work, as this bulletin explains, is in better condition and more promising from actual results at the present time than ever.

The State Forester cannot refrain from saying also that what Massachusetts is doing in this work is indirectly as important to the nation generally; for what is here accomplished will ultimately result in equal value throughout New England and finally elsewhere.

ACKNOWLEDGMENTS.

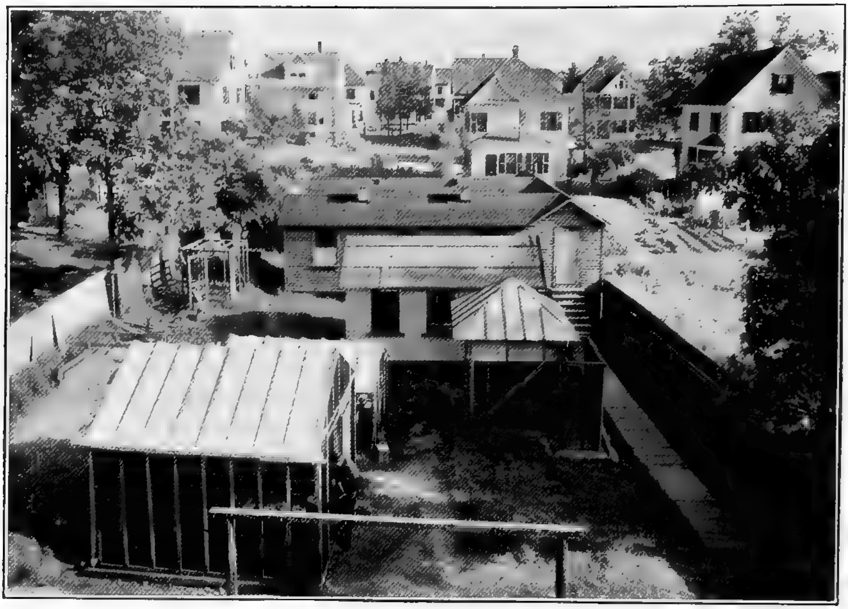
The work of writing and compiling the data in this bulletin was done by Mr. W. F. Fiske, agent and expert, Bureau of Entomology, United States Department of Agriculture, in charge of directing the technical work of introducing the parasites and predatory enemies of the gypsy moth and the brown-tail moth into Massachusetts. The headquarters for this work are at the State laboratory at Melrose Highlands.

When it was determined by the State Forester that the information contained in this bulletin would be appreciated by our people, a conference with Dr. L. O. Howard, the United States Government Entomologist, who has been our chief adviser in expending the State's money for this work, resulted in his delegating Mr. Fiske to the task. Mr. Fiske's manuscript was examined and approved by Dr. Howard.

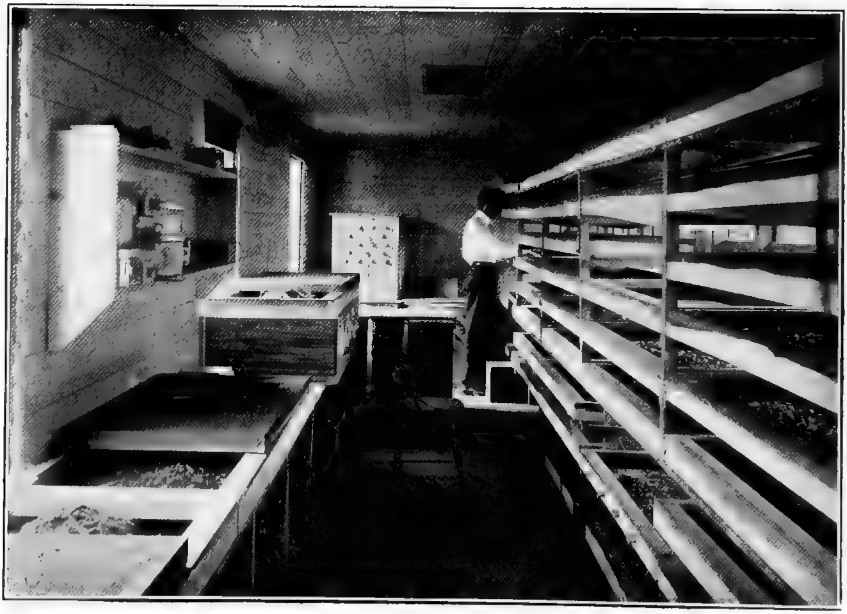
We are therefore under obligations to both of the above-named gentlemen for their hearty co-operative efforts in our behalf.

F. W. RANE,
State Forester.

6 Beacon Street, Boston, Mass., March 15, 1910.



Grounds of the Gypsy Moth Laboratory, showing Temporary Structures used in rearing Parasites of the Gypsy Moth and Brown-tail Moth.



Interior of One of these Structures, showing Trays for feeding Caterpillars.

PARASITES OF THE GYPSY AND BROWN-TAIL MOTHS.

NATURE OF INSECT PARASITISM.

It is probable that the total number of different species of insects which are native to Massachusetts is not far short of 10,000, if indeed it does not exceed this number. A large proportion of these are plant feeders, some of them sucking the sap, others eating the foliage, and others still boring in the roots, seeds or stems. A great many feed upon dead vegetable matter, or upon the lower plants, such as mushrooms and other fungi.

Several thousand, possibly half of the total, feed upon animals or upon dead animal matter, and by far the larger part of these prey upon other insects, — principally, but by no means exclusively, upon those which are plant feeders. It is largely through this continuous warfare that the plant-feeding insects are held in check, and prevented from increasing to such numbers as to become a menace to vegetable life in general.

The insects which subsist upon other insects may roughly be divided into two classes, according to the methods of their attack. The predatory, like the other predatory animals, wander about, attacking and devouring the weaker species or individuals. For the most part they are very catholic in their tastes, and will attack almost any other insect which they may chance to encounter in their favored haunts. The parasitic, on the contrary, are in most instances very closely restricted in the choice of their prey, and have a very different method of attack.

Instead of falling upon and devouring a weaker insect, they frequently attack and destroy those which are much larger and stronger in every way than themselves. This is accomplished by the deposition of an egg, or in some instances a living maggot, within or upon the body of the selected victim, or upon its food, or in some other situation. The young larva, hatching from the egg (or deposited by the female parasite, for in quite a large number of them the eggs hatch within the body of the parent), ultimately becomes established within or upon the body of the other insect, which serves as host; and, although there is considerable variation in the ways by which this is accomplished, the end is the same.

Having become established, the young larva proceeds to feed upon the less vital portions of its victim, usually upon the fatty tissues, until it is nearly or quite full grown; then, from its point of vantage inside the body of its host, it kills it, devours all or such portions of its body as it desires, and later transforms to a pupa, which in turn produces an adult similar to that which made the original attack.

There is hardly a plant or shrub or tree which is not attacked in some portion by one or more species of plant-feeding insects. Some trees, like the oak and pine, support a very great variety, which are widely diverse in their habits, and each of which confines its attack to a limited portion of the tree. Those which bore in the bark, for example, are always different from those which feed upon the foliage or which are nourished by the seed. Similarly, there is hardly a single plant-feeding insect which is not attacked by one or more different parasites, each of which is limited in its attack to some stage in the development of the particular species which serves as host. The parasites which attack the caterpillars of a plant-destroying insect, like the gypsy moth, never attack the pupæ or the eggs; but there are other parasites which do attack these stages.

Plant-feeding insects very rarely attack more than a few sorts of plants or trees. Some, like the gypsy moth, are very general feeders, and will eat the foliage of pine and fir as well as of oak and birch; but the number which feed upon both pine and oak are very few, and even the gypsy moth displays a strong preference for the foliage of broad-leaved trees. There are a great many which will feed upon nothing but oak, and there are many which are even more restricted, and which are never found on more than one kind of oak. Exactly the same is true of the parasites: some are general feeders, and will attack a great variety of hosts; others are extremely particular in this respect, and will not attack, or, if they are forced to attack, their young cannot develop upon, more than a very limited number of hosts. The great majority are thus closely restricted in their host relations, and the parasites which are most effective in controlling the increase of plant-feeding insects are generally of this character. It is on account of this that the many hundreds of different parasites of native caterpillars do not, and cannot, attack and control an insect like the gypsy moth, which is different in many respects from any native American insect.

NATURAL CONTROL OF THE GYPSY MOTH.

With the exception of the parasites, nearly every, and probably every, controlling agency which works to keep the gypsy moth within bounds in Europe and Japan is present in America. Mortality through catastrophic causes, such as storms and climatic changes, is heavy here, as it is abroad. It is probable that the birds, which destroy so many of the caterpillars, pupæ and moths, are equally effective in both Europe and America. Disease, induced through overpopulation, is more prevalent in some parts of Massachusetts than in those countries where overpopulation is not so apt to occur; and a multitude of predatory insects, notably, the bugs described by Mr. Kirkland in the report on "The Gypsy Moth," by Forbush and Fernald, render great assistance. So effective are these various agencies, that, taking the older infested section as a whole, the gypsy moth is practically at a standstill so far as permanent increase in numbers is concerned. Its numbers cannot be said to decrease to a noticeable extent, except as the immediate result of artificial repression, and it has reached its maximum possible abundance. If it had continued to increase at a rate of only twofold annually, it would by 1909 have been thirty-two times as common as it was in 1904 in tracts of woodland where artificial suppression could not be economically employed. This is obviously not the case.

Even in newly infested territory, where the controlling effect of starvation and disease is hardly or not at all apparent, an increase of six-fold annually[1] during the first few years is about all that is expected; and when it is considered that the number of eggs deposited by one female is frequently in excess of 500, it is at once evident that natural causes are responsible for the destruction of a tremendous percentage. Five hundred eggs, developing into an equal number of males and females, would result in the deposition of 250 egg masses the summer following, or an increase of two hundred and fifty-fold. If only a six-fold increase in the number of egg masses results, it is evident that 244 of the females must be destroyed at some time during their life; in other words there is an approximate mortality of no less than 97.6 per cent. annually in Massachusetts, due to natural causes.

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[1] Forbush and Fernald: "The Gypsy Moth," p. 94.

So, to reduce the number of survivors as to permit of *no* annual increase, on the average, in territory where the gypsy moth is not sufficiently abundant to become a pest, is the hope and aim of the work of parasite introduction. As already stated, there is no steady increase of the moth in the central most badly infested sections of the area of infestation; but the control brought about by famine and plague within this area is so exclusively dependent upon overpopulation, which is to say, upon a superabundance of the moth, as to make very probable a continuation of the present conditions for an indefinite period, unless some other factor becomes operative.

PARASITE INTRODUCTION IN THEORY AND PRACTICE.

If, as is believed by those who have the matter most at heart, the only important controlling agency which is lacking in America is the presence of the parasites which are such effective factors in its control abroad, the introduction of these parasites into America and their establishment here is all that is necessary to bring about the reduction of the gypsy moth from its present pre-eminence as a destructive pest to that of an innocuous or rarely noxious insect. The problem at first sight seems simple, but, like most undertakings, it develops complications in its practical solution.

Long before the work of parasite introduction was begun, all of the published records of European parasites and other enemies were well known to the Bureau of Entomology, which for years had been keeping track of such observations, and had accumulated a card catalogue with more than 20,000 references. As soon as work was begun, additional information concerning gypsy and brown-tail parasites was secured from European and

Japanese entomologists, who were most generous in their offers of assistance and advice. At the same time, it must be admitted that the sum total of available and absolutely reliable information was far from adequate. Long lists of parasites had been compiled[1] but these records were based upon the notes and observations of entomologists who were not particularly interested in the possible practical side of the question, and very frequently their records amounted to little more than the bare fact that a certain parasite had been reared in connection with the gypsy moth or the brown-tail moth. Furthermore, the same parasite was sometimes referred to by different entomologists under different names, or different parasites were considered to be the same, and on this account hardly any dependence could be placed on many of the records, and the doubt was reflected upon others. With very rare exceptions, nothing was published which gave any clue to the relative importance of the different species, and in several instances a secondary parasite was recorded as attacking the gypsy moth itself.

The work in the beginning was largely experimental, being an effort to determine ways and means for securing the parasites in a living and healthy condition. This accomplished, it became necessary to make a critical study of the various species secured, to determine, first of all, whether they were truly primary enemies of the moth, or whether they were present in some other connection. If they proved to be primary parasites and true enemies of the gypsy moth, they were liberated as rapidly as they could be imported and reared. As the work progressed, the various species were studied in greater and greater detail, and were ranked according to their relative importance in the countries to which they were native, and according to their methods of attack. Every effort was made to learn the main facts in the life and habits of each, and to become familiar with the conditions necessary to insure the establishment of each species in Massachusetts.

Upon numerous occasions knowledge of this character has been of the greatest value in suggesting the methods of importing, handling and colonizing the parasites, and in some instances it was essential to success. The work has been seriously handicapped through the practical necessity of entrusting the actual work of collection and shipment in foreign countries to others than those most familiar with the nature and needs of the various parasites. The several trips which Dr. Howard has made abroad, wholly or in part in the interest of this undertaking, has enabled him to meet the foreign agents, and to enter into explanations which were infinitely more satisfactory than any which could be effected through correspondence. At the same time, it has been impossible to convey to these agents the detailed information which would enable them to work to the best advantage, nor would it be possible for them to acquire this in any manner short of actual experience in the laboratory. In particular has it been handicapped by the very short period during which work upon any particular parasite could be carried on in any one year. Parasites of the pupa, or of certain stages of the caterpillars, could be collected in Europe or Japan only during the season when pupæ or caterpillars in those particular stages occurred in the open in those countries; and the aggregate period during which it has been possible to work with some parasites in the five years since the inception of the work does not exceed as many months.

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[1] Howard: "Insect Life," vol. 2, p. 210. Forbush and Fernald: "The Gypsy Moth," pp. 377 and 387.

In all, there have been received at the laboratory in a living condition between 40 and 50 species of parasites of the brown-tail moth and of the gypsy moth. Of these, about 30 attack the gypsy moth, but only about two-thirds of that number can be considered as at all important. The others seem always to be rare in the countries to which they are native, and never to become so abundant as to affect the increase of the moth. No parasite, however rare it might seem to be, has been ignored, once it was demonstrated to be a primary upon the gypsy or the brown-tail. A great deal of time has been spent in attempting to discover the probable reason for apparent inconsequence in so many instances; and a great deal of work has been done to demonstrate that this was due to other causes than defective methods in the collection and subsequent handling of the parasite importations.

One by one, as material has been imported under different conditions and from different countries, different species of parasites have been added to the list, until it has exceeded in gross numbers any list of parasites of the gypsy moth which has ever been published. One by one, as these parasites have been received and studied, they have been rated according to their habits and importance in the countries from which they came, and those which have failed to show promise of ever becoming of value in America have been eliminated. One by one, different species have been liberated in America under the most favorable conditions which could be provided for their establishment, until at the present time there are only 3 or 4 out of a total of 20 (which may be considered as including all of the promising parasites of the gypsy moth in Europe and Japan) which have not been liberated here, or which are not on hand ready for liberation as soon as the proper season shall arrive. The others, tentatively considered as of possible value, are very rarely common in any country; and partly on this account, and partly on account of the extraordinary difficulties which stand in the way of their successful importation, it has been impracticable to determine whether they are to be ranked as promising, or not. It is very likely that they will prove to be of a distinctly minor importance when they shall have been thoroughly investigated.

SEQUENCE OF PARASITES.

There is one very important factor which must be taken into consideration and thoroughly understood before it will be possible intelligently to discuss the work which has been accomplished in the importation of parasites of the gypsy moth. Briefly stated, it is that no one parasite is capable of effecting the necessary amount of control in an insect of the character of the gypsy moth, and capable of a similarly rapid rate of increase when unchecked by parasites; but a sequence of parasites, which will attack the insect in different stages of its development, and all the component members of which will work together in harmony, is absolutely necessary before the best results may be expected.

It has already been stated that the different parasites of one host are limited in their attack to certain stages in the development of this host. In the case of the gypsy moth, there are some which attack the egg, others the young caterpillars or the older and larger caterpillars, and those which form still another group reserve their attack until such time as the caterpillars have spun up preparatory to their transformation into pupæ, or until after this transformation has taken place. It is confidently believed that representatives of each of these three or four groups will have to be established in America before any marked results of a practical nature can be expected.

There are two exceedingly good reasons for believing this, which may be mentioned here besides others equally good, but less easily expressed in non-technical language. One of these is the fact that in not a single instance has one species of parasite been found sufficiently abundant abroad to bring about the percentage of destruction which will certainly be necessary in order to offset the six-fold rate of increase of the gypsy moth, which it is the consensus of opinion exists in newly infested territory in America at the present time. The other is, that there is not a single species of defoliating caterpillar, similar in habit to the gypsy moth, of which the parasites have been studied, and which is controlled by them to any extent, which does not support a sequence of parasites similar to that which it is proposed to establish for the gypsy moth.

If the theory as to the necessity of a sequence of parasites be accepted as a general rule, its importance cannot be overestimated. Success in the work of parasite introduction will then depend entirely on whether or not a sufficient variety of parasites can be established in America, and cannot obtain until all of the species which go to make up a natural and effective sequence are established, and have increased to a sufficient abundance to make each of the chain effective in its own particular field. The predaceous beetles alone can never bring about the desired end, neither can the egg parasites, nor those of the pupæ, nor, it is believed, can all these three groups together. The parasites of the caterpillar, in addition to these others mentioned, ought to bring about the desired end. The Calosoma beetles bid fair to assist the native predatory enemies materially in the good work which they are doing, and their establishment will make that which is expected of the parasites easier and more certain of accomplishment.

It ought to be stated, in this connection, that this principle,

PLATE II.

Large Shipment of Parasite Material received in 1909 from France.

Gypsy Moth Laboratory, Exterior. Lot of Packages of Parasite Material just received.

while it has been recognized as one applicable in many instances, has been established much more firmly than ever before, as a result of the work which has been done at the laboratory. It would be impossible to speak with so much assurance had it not been for a series of investigations upon the parasites of several native insects, similar in certain important respects to the gypsy moth. These investigations have seemed sometimes to be outside of the main point at issue; but their value in establishing, as they have, this and certain other general propositions, has justified many times over the relatively small expenditure necessary to carry them on.

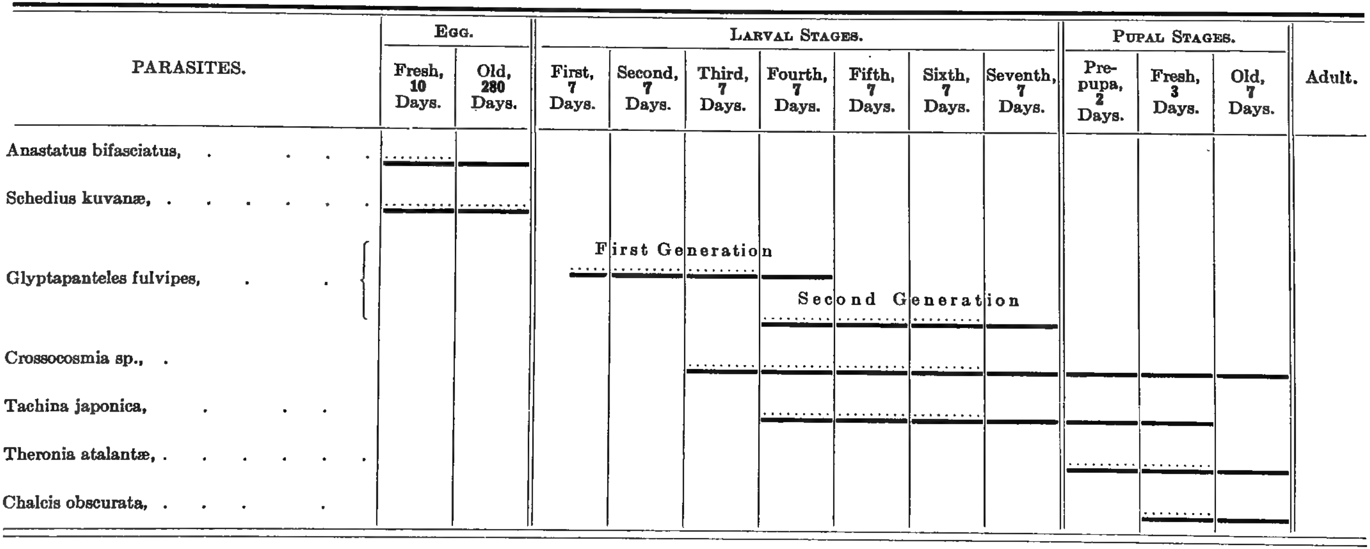
PARASITES OF THE GYPSY MOTH IN JAPAN.

The Japanese race of the gypsy moth is larger and stronger and in certain other respects different from that found in Europe or in America. One important characteristic is its greater fecundity, the number of eggs in a mass being from one-fourth to one-third greater, on an average, than in the egg mass of the typical European variety. This is indicative of greater powers of resistance to natural controlling factors, and, conversely, of the existence of more effective controlling agencies in Japan than in Europe. It is very significant that it is not at all an important pest in Japan, and that, in the opinion of the native entomologists and of every American entomologist or otherwise trained observer who has had opportunity to acquire first-hand information, the parasites are very effective in its control.

Thirteen species of primary parasites have been reared from eggs, caterpillars or pupæ of the gypsy moth from Japan, but only 7 of these can be considered as of importance in bringing about its control. The others have been consistently rare, and some of them have never been recorded as parasites by the Japanese themselves.

These parasites, in every instance but one, are either identical in all respects, or, if not absolutely the same, exceedingly similar to the parasites in Europe. It is unfortunately necessary to refer to them by their technical names, since none of them have been considered as of general interest hitherto, and other than such names there are none. They are listed in Table 1.

TABLE 1.—*The Gypsy Moth.—Sequence of Parasites in Japan.*



How they work in effecting the control of the moth in their native country is best indicated in the table, which, while it needs explanation, tells the story much plainer than it would be possible to tell in words. Opposite the name of each parasite, extending across a certain number of the vertical columns, is a dotted and a solid line. The vertical columns indicate different stages in the development and transformations of the gypsy moth, as egg, caterpillar and pupa, and these are still further divided into caterpillars of different sizes and eggs and pupæ of different ages and conditions. At the head of each column is stated the approximate number of days during which the individual gypsy moth remains in that particular stage.

The dotted line following the name of the parasite indicates those stages in the life of the gypsy moth during which it is liable to be attacked by the parasite in question, and it will be seen that in a number of instances, as, for example, Chalcis and Theronia, this period is exceedingly short. The solid line indicates the stages in the life of the gypsy moth during which it is likely to contain the parasite in its body. This, it may also be noted, varies considerably. Crossocosmia, for example, gains lodgment in the active caterpillar while it is only about half grown, and the extension of the solid line across all of the columns which stand for the later caterpillar stages, as well as for all of the pupal stages, indicates that the larvæ of this parasite do not leave the host caterpillar until after it has transformed to a pupa, and until the moth would naturally have emerged had the pupa remained healthy and unparasitized.

The main fact, which it is particularly desired to emphasize, is that every stage in the transformations of the gypsy moth, from the time the eggs are first deposited until the caterpillars are full grown and transformed to pupæ, is subject to the attack of one or more parasites. It is also liable to attack at any time throughout this period except during the cold weather in the winter, when there is no insect activity. This is exactly what is meant by the sequence of parasites, and, in the opinion of those most thoroughly informed, it is the condition which it is absolutely necessary to bring about in America before complete control can be effected.

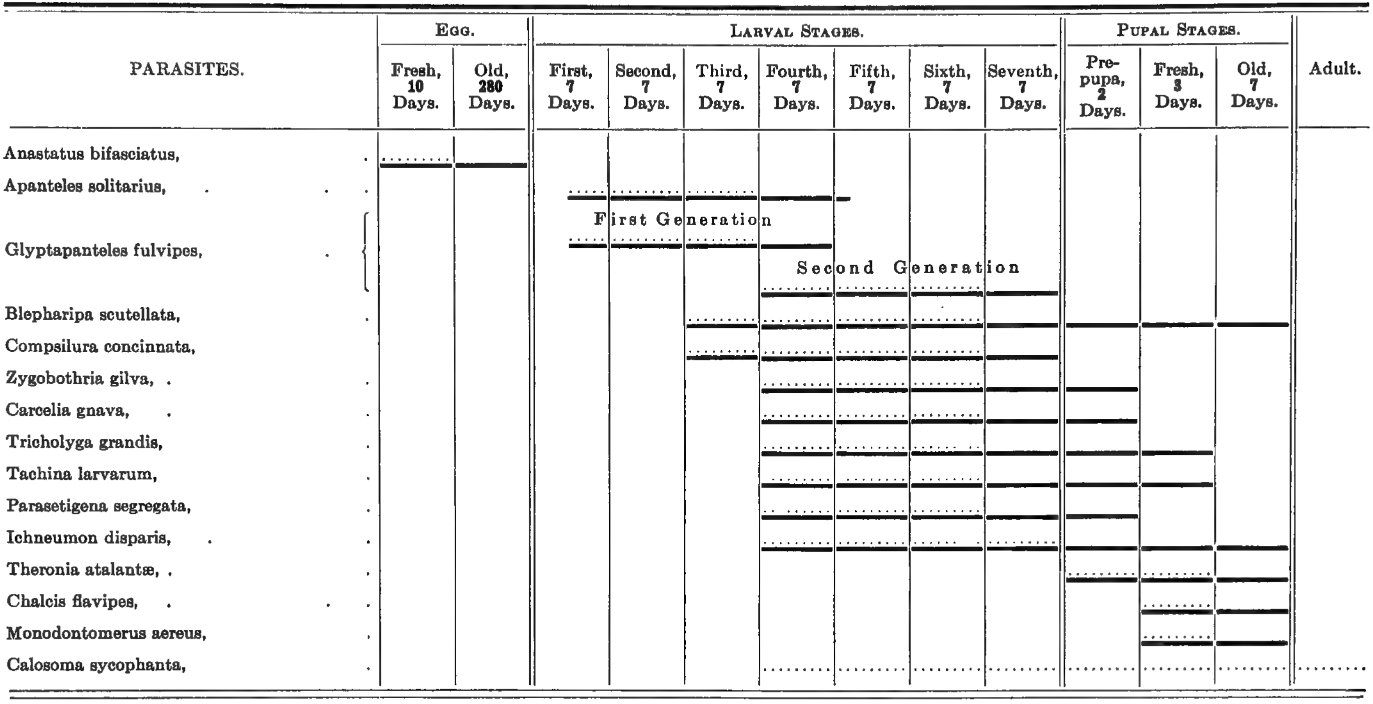
PARASITES OF THE GYPSY MOTH IN EUROPE.

Table 2 is similar in construction and illustrates the parasitism of the gypsy moth in Europe. There are at least 22 species, and possibly one or two more of slight importance, known to attack the moth in various European countries, and of these, 15 are considered to be important. Of the 22, 2 are identical in all respects with 2 which occur in Japan, and are considered to be the same species. Six or 7 are quite distinctly different from any which have yet been received from Japan, and it is impossible to separate the remainder from the Japanese species by habit and method of attack alone. The most of them, however, appear to be different in their final appearance as adults, and are considered, for the present, as representing different species.

There are several reasons why there should be a longer list of European than of Japanese parasites, principal among which is the greater variety of climate represented by the different European countries. Some of the parasites are confined almost exclusively to the Mediterranean region, others to Russia and eastern Europe generally, while others are more common in the northern, central and western portions. It is almost certain that other parasites will be found in other parts of the Japanese empire from which small quantities of parasite material have been received, but it is very doubtful if any of importance will be added to the list from European sources.

It will be noted, if the table is scrutinized, that exactly the same conditions as regards the sequence of parasites obtain in Europe as in Japan. As in the table first given, every stage of the moth from the newly deposited egg to the pupa is open to attack by one or more species of parasite, and the sequence is perfect.

TABLE 2.—*The Gypsy Moth.—Sequence of Parasites in Europe.*

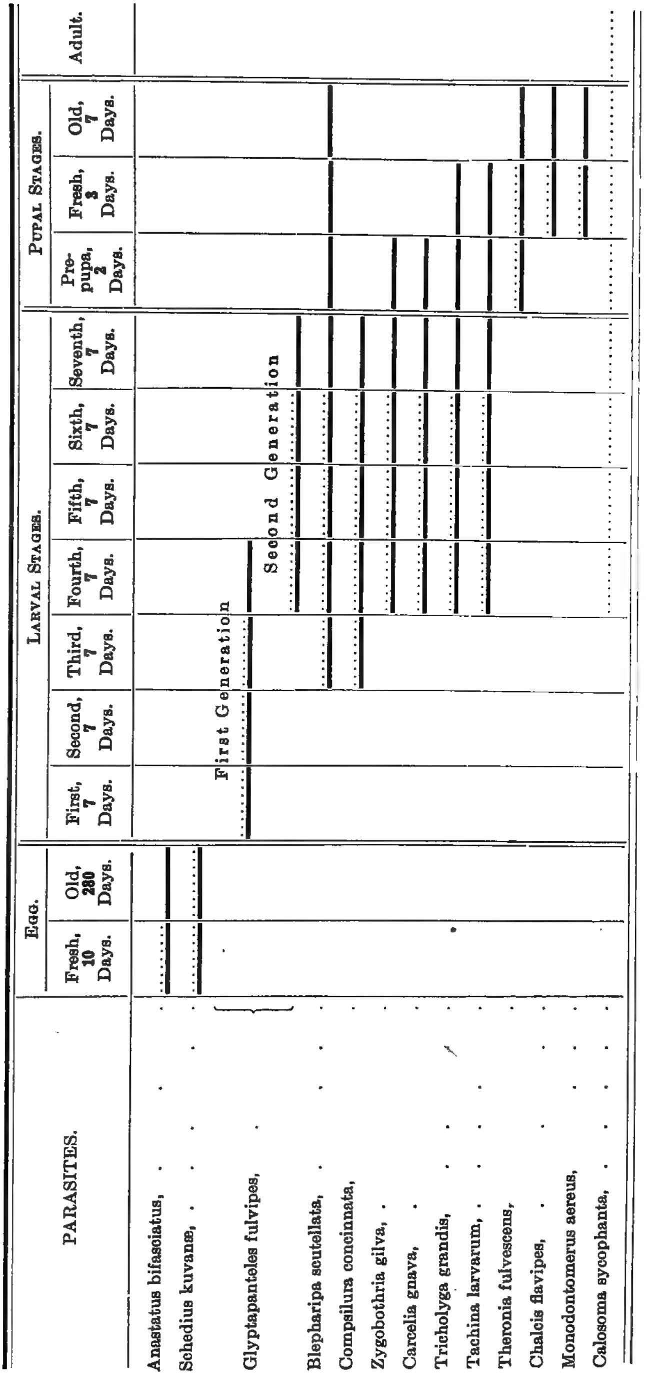


PARASITES OF THE GYPSY MOTH IN AMERICA.

There is just one parasite of the gypsy moth in America, native to the country, which ranks in importance with the least of those included in the tables of Japanese and European parasites. This is Theronia, and the native species is so similar in habit as to be indistinguishable from the other species of the same genus which attack the same host in Europe and Japan, and it cannot as yet be stated with assurance that it is not the same. It is literally the least important of all of the parasites listed, and the maximum effectiveness in America is, if anything, less than in any foreign country. It cannot be credited with destroying more than 1 in 30 or 1 in 50 of the pupæ, on the average, and never more than 1 in 10 under the most favorable conditions ever observed. A table of the native parasites of the gypsy moth (leaving out the rare and inconsequential species), prepared for comparison with those of the European and Japanese, would consist of this species and no other, and the difference is obvious.

In Table 3 are listed all of the parasites which have been received from Europe or Japan in sufficient numbers to make possible satisfactory colonization in America. There are 4 or 5 more which have been liberated in small numbers, or which are on hand ready for liberation in the spring, including *Tachina japonica* and *Chalcis obscurata,* Japanese representatives of the European species, and having nearly identical habits. There are also on hand at the laboratory a large number of the hibernating puparia of *Parasetigena segregata* and *Crossocosmia* sp., both of which are parasites of some promise, and neither of which has yet been colonized.

TABLE 3. — *The Gypsy Moth. — Sequence of Parasites in America.*



It is not by any means assured that all of these parasites are established here, but it is possible that they are, or that they will be before another season passes. Some that are known to be living in the field, and which are apparently in a very good way toward becoming permanent fixtures in the American fauna, have had their freedom for less than one year; and there is no assurance that a species is established until it has completed at least one cycle of the seasons unprotected in the open. A few of them, as will be shown later, will be the better for artificial assistance in dispersion, etc. One, Chalcis, ought to be imported in larger numbers, but with this one possible exception, each that is listed has been liberated under the most favorable circumstances which it is possible to provide.

Especial attention is called to the fact that the sequence is complete as it stands. Every stage of the moth is provided with a parasite which will attack it, if given the opportunity, and in every respect the table compares favorably with that illustrative of the Japanese parasites or of the European. It represents, in this most important respect, the climax of the endeavors of the past five years, and it has been accomplished only during the past five months. If the writer were assured of the firm establishment of each of the species listed, and that each would become as efficient in Massachusetts as it is in the countries from which it came, he would state without reservation that the work of parasite introduction was successfully accomplished.

The reader must not confuse the accomplishment of parasite introduction with the accomplishment of the end which it is desired to achieve. It goes without saying, when the habits of the parasites are taken into consideration, that the few paltry thousands, which it has been possible to secure through methods of importation which were the best which experience could devise, must be allowed sufficient time to increase to the millions and billions necessary to cope with the tremendous quantities of gypsy moths which are everywhere in evidence throughout the infested district, wherever the expensive methods of hand suppression have not been employed.

Fortunately, this increase, if it follows colonization, will be by geometrical progression, exactly as has been the case with the gypsy moth; and it will, most fortunately, be much more rapid

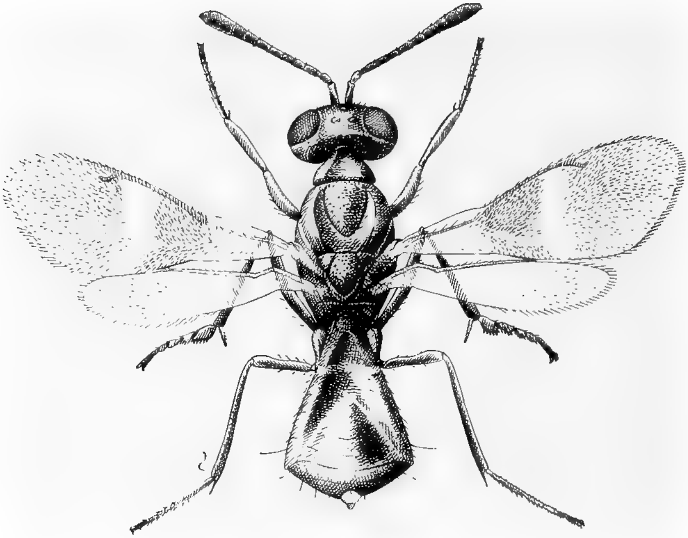


FIG. 1. — *Anastatus bifasciatus*: gypsy moth egg parasite, adult female, greatly enlarged.

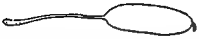


FIG. 2. — Anastatus: egg, greatly enlarged.

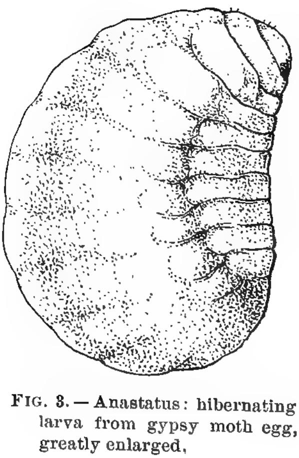


FIG. 3. — Anastatus: hibernating larva from gypsy moth egg, greatly enlarged.

than it was in the case of the gypsy moth, owing to the greater dispersive powers of nearly all of the parasites. With one exception, they more nearly resemble the brown-tail moth in this respect, being gifted with the power of flight; and, as is well known, the territory covered by this insect is much more extensive than that covered by the gypsy moth, although the latter was introduced into America more than twenty years earlier.

Another enormous step in advance, which has marked the progress of the work the present season, is the accumulation of certain valuable data which throw much-needed light upon the subject of parasite dispersion, and which have tended more than anything which has come about since the earliest beginning to encourage those who have been charged with direction of the work. For the first time it is possible to calculate, with some foundation upon fact, the probable outcome of the undertaking. It is difficult to do this on the small amount of absolutely authentic information at hand, and to vouch for the accuracy of the conclusions with any degree of assurance; but the attempt has been made, and will appear in the concluding paragraphs.

First, in order to make more clear the ground which supports these conclusions, a brief account of each of the introduced parasites of the gypsy moth will be given. No attempts have been made to go into technical detail concerning the lives and habits of these several species, further than is necessary to give a general idea of their methods of attack, and of the hopes and fears which are felt for the future of each.

Parasites of the Egg.

Anastatus bifasciatus.

This minute parasite (Fig. 1) attacks the newly deposited eggs of the gypsy moth during the brief interval which elapses before the embryonic caterpillars develop. Its eggs (Fig. 2) are deposited singly, one in each individual egg of the host, and its larvæ feed upon the substance of the host eggs and become full fed in about three weeks. They then enter on a long resting stage, snugly ensconced within the limited confines of the shell (Fig. 3), and do not resume activity until the middle of the following summer, ten months later. The transformations to pupa (Fig. 4) and adult (Fig. 1) follow in the course of two or three weeks, the latter emerge, and in a few days are ready to deposit eggs for another generation within the newly deposited eggs of the next generation of the gypsy moth. There is thus but one generation of the parasite each year, and its life cycle, which corresponds to the annual cycle, is correlated exactly with that of the insect which serves as its host.

It is a native of both Europe and Japan, and is sometimes a common and effective parasite in either country. It is very unevenly distributed, however, especially in Europe, and a great many lots of eggs have been received which did not contain any of the parasite. For two years large numbers of egg masses were imported from various European and Japanese localities, and not a single specimen was secured. Finally, in the spring of 1908 it issued almost simultaneously from Russian and from Japanese eggs, and was soon determined to be a primary parasite. About 500 individuals were liberated that summer, but under conditions which were unsatisfactory in many respects, and no reproduction in the field resulted, so far as has been determined.

Encouraged by the knowledge that there was an egg parasite which could be secured through the winter importation of eggs, — a fact which was far from being established up to the rearing of the first specimens of Anastatus, — larger importations from numerous localities were made during the winter of 1908–09. As before, only a part of these shipments were productive, but among them was one consisting of five sacks of about 1,000 egg masses each, from Professor Jablonowski of Budapest, which were collected in five different Hungarian localities. From three of these only an insignificant quantity of parasites was secured, one lot being entirely unparasitized. From two, however, was secured by far the largest number of egg parasites ever received from any source, there being more than 80,000 all told. It illustrates very well the uneven distribution of the species in Europe.

These, together with some others from other sources, were liberated in five colonies, in quite widely separated localities

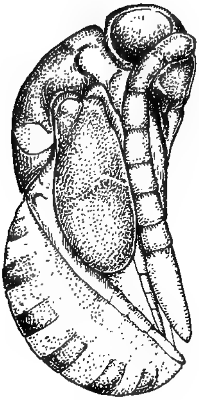


FIG. 4. — Anastatus: pupa from gypsy moth egg, greatly enlarged.

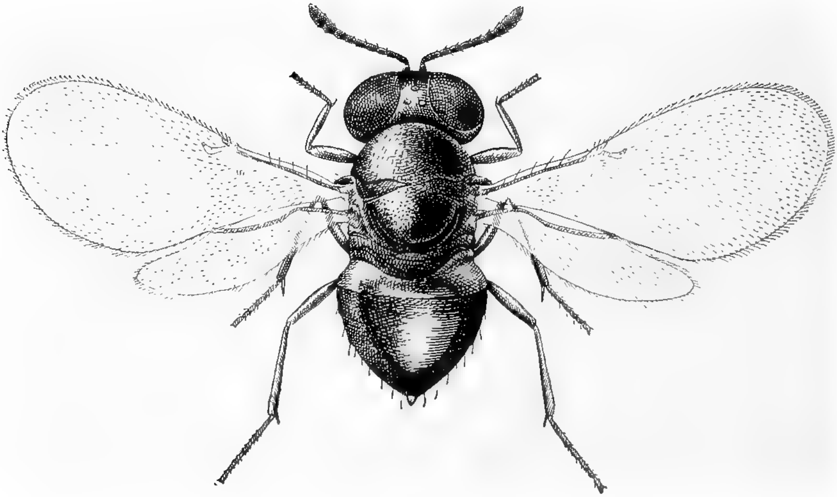


FIG. 5. — *Schedius kuvanæ:* Japanese parasite of gypsy moth eggs, adult female, greatly enlarged.

within the infested area. In every instance they attacked the freshly deposited eggs of the moth with avidity, and reproduction in the field under perfectly natural conditions resulted. At the present time there are many thousands of the larvæ of the parasite hibernating in the open in the immediate vicinity of the colonies, exactly as they would do in their native land, and there is hardly room to doubt that they will issue next summer in the normal manner.

In one respect only is the insect disappointing. It appears to resemble the gypsy moth, in that the females do not fly. The utmost endeavors have been made to determine accurately the distance to which it travelled from each of the points where it was liberated, and the results indicate that 100 feet is about the limit. This is a rate of dispersion slower than that of the gypsy moth itself, and it would take a great many years for the parasite to spread over the entire infested area. Additional importations will be made during the present winter, and it is hoped that a large number of colonies will be established next summer, but no immediate benefits can be expected.

Schedius kuvanæ.

Most fortunately it is not necessary to depend exclusively upon the Anastatus as a parasite of the eggs of the gypsy moth, for in Japan there is another (Fig. 5) with similar habits, in so far as the object of its attack is identical; outside of this fact, it is different in many important particulars. Instead of confining its attack to the freshly deposited eggs, it rather prefers those in which the embryonic caterpillars have developed, and, since these caterpillars are fully formed, and so far as appearances go ready to hatch within three weeks after the eggs are deposited in the summer, Schedius is actually a parasite of the unhatched caterpillar, rather than of the egg. Instead of requiring a full year to complete the life cycle from egg to adult, it completes a generation once every three or four weeks during the warmer part of the summer, or in the winter if kept in rooms properly warmed. It is thus able to go through at least two generations during the fall, after the eggs of the moth have been deposited, and before cold weather puts a stop to its activity.

The history of its introduction into America is most interesting, and, except for the fact that it was so long delayed in execution, forms one of the most satisfactory episodes in the entire work of parasite introduction.

As long ago as the spring of 1907 a few dead adults were secured in an importation of gypsy egg masses received during the winter from Japan, but none were living on receipt. During the winter next following larger importations were made, and many thousands of eggs, from which some parasite had issued, were found, but not a single living specimen was obtained. It was evident that it completed its transformations and issued in the fall, and that, if it hibernated in the eggs, it was warmed to activity while the packages were in transit to America, and the adult parasites either died or escaped en route.

In the fall, winter and spring of 1908–09 a large quantity of eggs of the gypsy moth were received from Japan, the shipments beginning early in the fall and continuing until nearly time for the caterpillars to hatch in the spring. The first, received in September, contained hundreds, possibly thousands, of the parasites, which had issued from the eggs en route, and all of which, as usual, had died; not a single living individual was received. Specimens were referred to Dr. Howard, who found that they represented an entirely new and hitherto undescribed species, which he named after Professor Kuwana, who collected and sent the eggs from which they had issued. A single pair of living specimens rewarded the careful attention which was lavished upon the importations received later in the fall and during the winter, and it was not until April, 1909, that a mated pair could be secured. During that month a total of 11 individuals issued from cages containing Japanese eggs recently received.

This small number served as the beginning of a series of experiments in propagation, which succeeded so well that in August several thousands were available for liberation in the field. In September and again in October additional colonies were established, and during the fall, some 50,000 in all were given their freedom.

After September the bulk of those reared were kept for extensive propagation work in the laboratory, and at the present time (February 1) a conservative estimate of the number in various

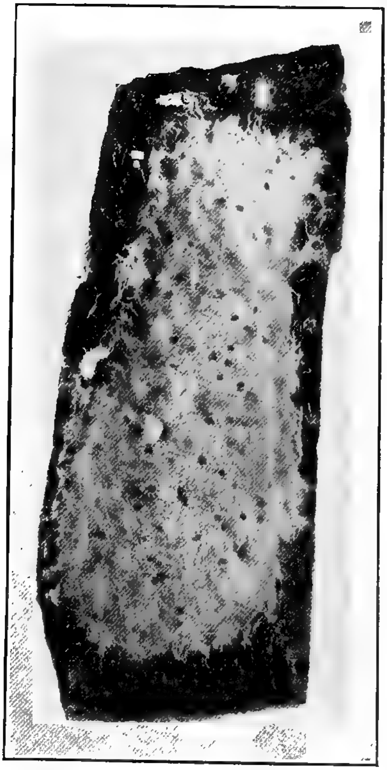


FIG. 6. — Gypsy moth egg mass, showing exit holes of Schedius, enlarged about four times.

stages in the reproduction cages is 2,000,000. It is by no means sure that the species will go through the winter in the open as successfully as is hoped will be the case; but no obstacle threatens to prevent the liberation of several millions of the parasite during the summer of 1910.

The reproduction of the parasite in the field, as a result of the earlier attempts at colonization, has been far in excess of expectations. The rate of reproduction in the laboratory, which averages only about ten-fold each generation, was greatly exceeded, and hundreds of thousands of eggs were known to be parasitized in the immediate vicinity of the colony sites. In the one colony which has been most carefully watched the parasitized eggs (Fig. 6) average some 30 to the mass everywhere within a radius of 50 yards, and the masses in a few places are so thick as to hide the bark on the trees. Beyond 50 yards the numbers fall off very rapidly; but the species has been found several hundred yards from the point of liberation, in striking contrast to Anastatus, which traveled only 100 feet.

It is hoped that a strong colony will be established in every town in the infested district during the coming summer; and if the same rate of dispersion indicated during the past fall continues, and the parasite demonstrates its ability to exist under American conditions during the entire year, it should be generally established throughout the infested area in two or three years more.

It must not be forgotten, however, that it has not yet proven itself adaptable to American conditions at all seasons. Like the other egg parasite, Anastatus, the only known host is the gypsy moth; but, unlike that species, its life is not correlated to that of its host. It is not known how it passes the winter, and, although living adults issue within a few days from egg masses brought in from the vicinity of the colonies in December, it is possible that they will not survive the cold weather which is bound to follow in January and February.[1] There is also a possibility that in Japan there is some other sort of egg subject to its attack, in which it passes a generation during the early summer, before the eggs of the gypsy moth are available, and that there will be no native insect which will give what may prove to be some such necessary aid to its continued existence.

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[1] This statement was written in December. It has since been found that all of the larvæ and pupæ of the parasites perished during the cold weather in January, but that adult parasites, of which there are known to be many in the field, lived through it. Whether they will survive the remainder of the winter is yet to be demonstrated.

PARASITES OF THE CATERPILLAR.

Glyptapanteles fulvipes.

Although this was almost the first parasite of the gypsy moth which attracted any attention in Massachusetts, and the first which it was attempted to import after the beginning of active work, it was one of the last to be liberated under satisfactory conditions, and its establishment in America is not yet certain. Extraordinary methods were necessary to bring it to America living and healthy, and it was not until Prof. Trevor Kincaid, who was selected by Dr. Howard as the best available man for the purpose, visited Japan, and personally superintended the collection and shipment of the cocoons, that success was achieved. The story of Professor Kincaid's experiences and of the difficulties which he met and overcame is interesting. He was accorded great and material assistance by the Japanese entomologists, and the work inaugurated by him in 1908, was continued with even greater success in 1909.

The adult parasite (Fig. 7) deposits a number of eggs beneath the skin of the active caterpillars, and any stage, from the first to and possibly including the last, may be attacked. The larvæ, hatching from the eggs, become full grown in from two to three weeks, and then work their way out through the skin of the still living caterpillar (Fig. 8) within the body of which they fed. Each spins for itself immediately afterward, for its better protection during its later stages, a small white cocoon. The number of parasites nourished by a single host varies in accordance with its size. There may be as few as 2 or 3 in very small caterpillars, or 100 or more in those which are nearly full grown.

The unfortunate victim of attack does not, as a rule, die immediately after the emergence of the parasite larvæ and the spinning of their cocoons, but it never voluntarily moves from the spot. Its appearance, both before and after death, surrounded by and seeming to brood over the cocoons, is peculiar and characteristic, and once seen can never be mistaken. (Fig. 9).

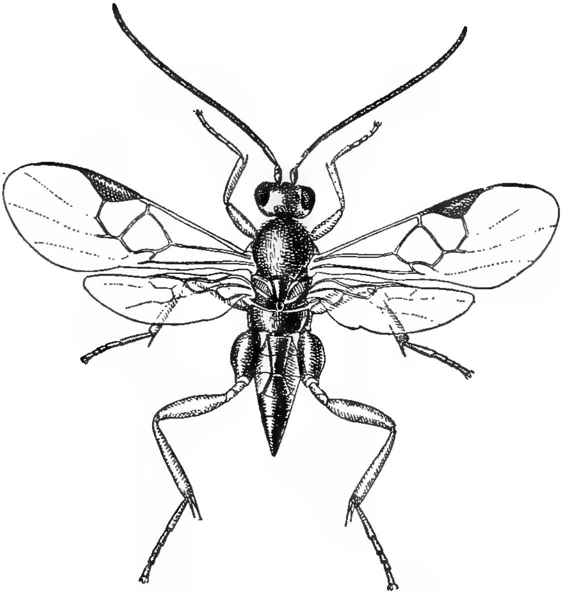

FIG. 7. — *Glyptapanteles fulvipes:* Japanese and European caterpillar parasite, adult, greatly enlarged.

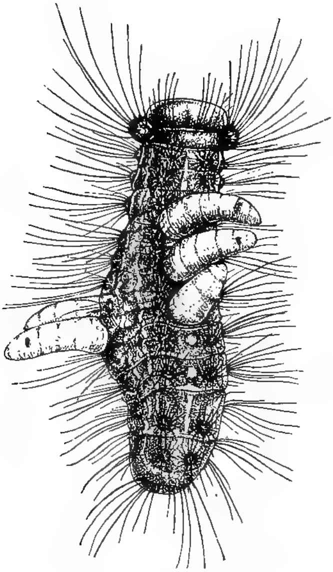

FIG. 8.—Glyptapanteles: larvæ leaving gypsy moth caterpillar, enlarged.

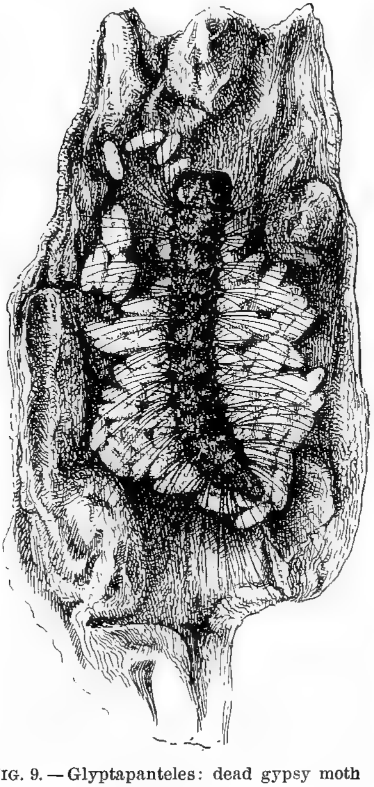

FIG. 9.—Glyptapanteles: dead gypsy moth caterpillar surrounded by cocoons of parasite, slightly enlarged.

There is ample opportunity for two generations of the parasite annually upon the caterpillars of one generation of the gypsy moth. This is the rule in the countries to which it is native, and is to be expected in America.

The parasite was described from Europe more than seventy-five years ago, and has been known to be a parasite of the gypsy moth for a long time. Later it was described under a different name from Japan, and the Japanese parasite was for a time considered to be different from the European. Absolutely no differences in life and habit which can serve to separate the two are known, and, as the adults are also indistinguishable in appearance, they are considered to be identical.

It has been the subject of frequent mention under the name of Apanteles, as well as of Glyptapanteles, in the various reports of the superintendent of moth work, from the first to the fourth; and Dr. Howard, in the account of his first trip to Europe in the interests of parasite introduction, tells of its occurrence in the suburbs of Vienna. Largely on account of the fact that it is much more conspicuous than many of the other parasites, it has attracted more general attention. The Rev. H. A. Loomis, a missionary, and resident of Yokohama, was the first to call attention to its importance in Japan, and made several unsuccessful attempts to send it to America. Dr. G. P. Clinton, mycologist of the Connecticut Agricultural Experiment Station, who visited Japan in 1909, observed the parasite at work, and reported most favorably upon its efficiency as a check to the moth. Numerous other attempts on the part of European and Japanese entomologists, including one elaborate experiment, which involved the shipment of a large wire-screened cage containing a living tree with gypsy caterpillars and the parasite, were made, but with uniformly ill success. Upon every occasion the parasites all emerged from their cocoons and died en route.

When every other means failed, Professor Kincaid, as already stated, was deputed to visit Japan, and to make all necessary arrangements for the transportation of the parasite cocoons in cold storage to America. The arrangements which he perfected provided for continuous cold storage, not only en route across the Pacific, but during practically every moment from the time the cocoons were collected in the field in Japan until they were received at the laboratory in Melrose. Events justified the adoption of every precaution, and, with all the care, only a small part of the very large quantity of cocoons which he collected reached their destination in good condition. Hundreds of thousands were collected and shipped, and less than 50,000 were received alive, — nearly all in one shipment in July.

The season in Massachusetts was early, and nearly all of the gypsy caterpillars had pupated by that time, so that there was no opportunity for the parasite to increase in the field upon this host that season. In 1909 the sites of the colonies were frequently visited, but not a single parasitized caterpillar was found which could be traced to colonizations of the year before. Keen disappointment was at first felt, but later developments have tended to throw a more encouraging light upon the situation.

In 1909 importations were continued, through the magnificent efforts of Prof. S. I. Kuwana of the Imperial Agricultural Experiment Station, at Tokio, with much more satisfactory results. In 1908 the season in Japan was very late, and it was not practicable to send any of the cocoons of the parasite until June and July; while in America the season was early, and by that time all of the caterpillars, as has already been stated, had pupated. In 1909 the season was rather early in Japan and correspondingly late in America; and besides, through special effort, Professor Kuwana was enabled to send a few thousands of the cocoons of the first generation, which reached the laboratory early in June. About 1,000 adults emerged from these cocoons after receipt, and the most of them were placed in one colony in a cold situation on the North Shore, where the caterpillars were greatly retarded, and where there were still some in the first stage. The remainder were colonized in warmer localities, where the caterpillars were one stage farther advanced.

Immediate success followed the planting of these colonies. Within three weeks cocoons were found in each, and the number of parasitized caterpillars was gratifyingly large. A very careful investigation was conducted, to determine the proportion which was attacked by native secondary parasites; and, while this was so very large in one instance as seriously to jeopardize the success of the experiment, it was not so large in the others.

There were several thousands of this first generation known to have developed in the open upon American soil, which issued from the cocoons some four or five weeks after the colonies were established, but in only that one on the North Shore, where the caterpillars were in the first and second stages when the parasites were liberated, was there a full second generation. Here the larger caterpillars were again attacked, and an abundant second generation of the parasite followed.

Meanwhile, additional shipments of cocoons of the second Japanese generation were received early enough to permit of a generation in the open upon the native caterpillars, and several other colonies were successfully established. It is known that there were many thousands of the parasite issuing in at least five different localities during August, but immediately thereafter they were completely lost to sight, and it is futile to hope to recover traces of them before another spring.

Until the late summer of 1909 nothing occurred to indicate that this parasite would be likely to fly for any great distance from the point of its liberation; and, as has been already stated, it was looked for in vain in the summer of 1909 in the immediate vicinity of the colonies of the year before. In July, 1909, a strong colony was planted in an isolated woodland colony of gypsy moths in the town of Milton. It was rather confidently expected that it would attack these caterpillars so extensively as to destroy the major portion; but it was the cause of some surprise, when the locality was visited after the parasites of the new generation had mostly issued from the affected caterpillars, to find a smaller number of cocoons than there were individuals liberated in the first place, and only about one-fourth, perhaps less, of the caterpillars attacked. The circumstance was as discouraging as anything which had gone before, and for a few days nothing happened to change its complexion. Then, to the intense surprise of the writer, Mr. Charles W. Minott, field agent of the central division, sent to the laboratory a *bona-fide* example of the parasite, which had been collected in the Blue Hills reservation, upwards of a mile away. There was no possible source except the Milton colony, and a spread of upwards of a mile in something under a week was indicated beyond dispute. At almost the same time the brood of Monodontomerus was found for the first time in pupæ of the gypsy moth in the field; and when the history of this species is considered, in the connection which it bears toward the circumstances surrounding the recovery of the Glyptapanteles so far from the point where it was liberated, the whole situation is altered.

Granted that the parasite disperses at the rate of one mile in each week of activity, and that it is able to adapt its life and habits to the climate and conditions in America, the chances are, that, instead of looking for it in the immediate vicinity of the points of colonization, it is quite as likely to be found almost anywhere in the infested area within 25 miles of Boston. If it is thus generally distributed, very large numbers in the aggregate may exist, and it may increase at a rate as rapid as that of Monodontomerus, and at the same time escape detection until the summer of 1911 or 1912.[1]

This is not only possible, but probable, unless a number of careful observers assist in the recovery of the parasite next season; and if any one should chance, at any time during the summer, to discover parasite cocoon masses similar to those figured, and will collect them and forward them in a small box to the gypsy moth laboratory, Melrose Highlands, Mass., the service will be greatly appreciated. There are a great many native parasites of native caterpillars which are very similar and in some instances indistinguishable from those of the Glyptapanteles, but none of these have ever been recorded as attacking the gypsy moth.

The one great fear in connection with the introduction of this most important parasite is that it will not find all of the natural conditions necessary for its continued existence in Massachusetts. Its life during the fall and its whereabouts during the winter are equally a mystery; and even the Japanese entomologists, who are the keenest of observers, resident in a country where it is a relatively common insect, are wholly unable to suggest a reasonable solution. It has been recorded upon a variety

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[1] The occurrence of the cocoons in the near vicinity of the colony sites immediately following the liberation is most natural, and in perfect harmony with the wide dispersion. The female parasites as soon as they emerge are ready to deposit a small part of the eggs which they will eventually deposit if they live and have opportunity. After the deposition of this part, it is necessary for them to wait an appreciable time before they are ready to deposit any more.

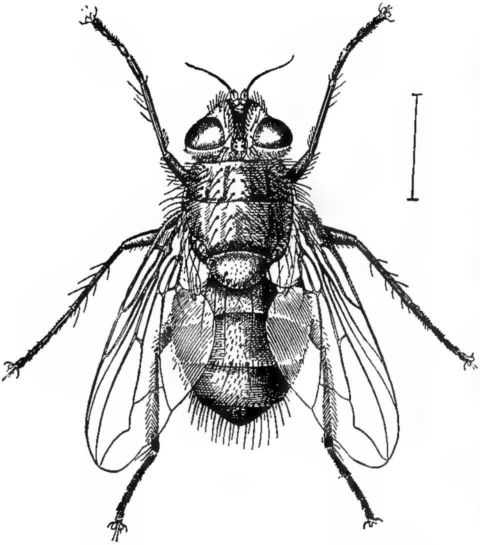


FIG. 10. — *Blepharipa scutellata:* important European parasite of gypsy moth caterpillar, adult, enlarged.

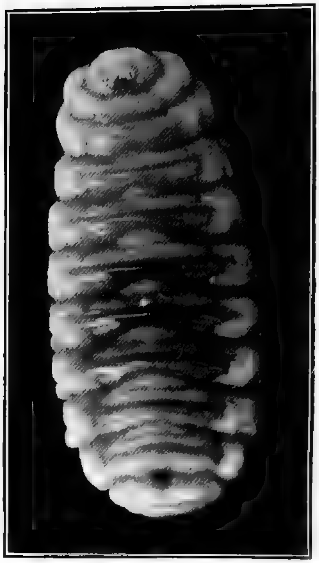


FIG. 11. — Blepharipa: full-grown larva from gypsy moth pupa, enlarged about six times.

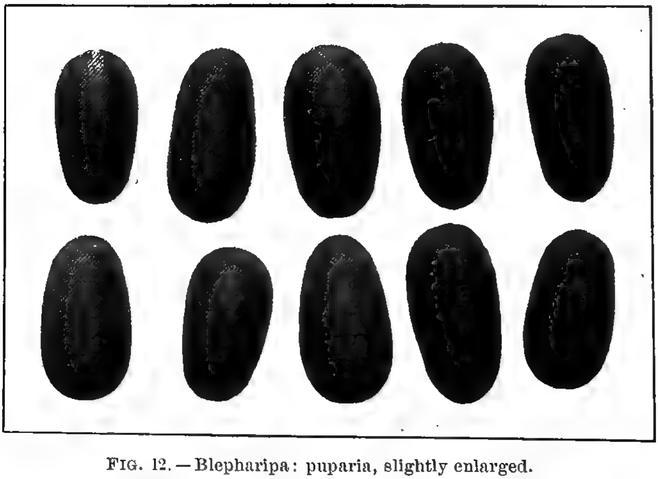


FIG. 12. — Blepharipa: puparia, slightly enlarged.

of other caterpillars in Europe, but these records are known to be erroneous in part, and all are likely to be so. As stated just above, there are numerous other species which are easily confused with it, but none of them appear to attack the gypsy moth; and, *vice versa,* absolute proof that the Glyptapanteles of the gypsy ever attacks any other host is at present lacking.

It is one of the most important parasites, perhaps the most important, and fills a gap in the sequence which it will be exceedingly hard to fill should it fail to become established. If it demonstrates its ability to live in America, it is safe to say that the greatest and most-feared of all of the obstacles to success will prove to be nonexistent.

Blepharipa scutellata.

Blepharipa belongs to a different order of insects, the Diptera, which consists of the true flies, while the egg parasites and Glyptapanteles belong to the order Hymenoptera, and are more nearly related to the bees and wasps. The latter are characterized by four membranous wings, while Blepharipa has but two wings, and is the first of the several parasites which will be mentioned which belongs to the family Tachinidæ of order Diptera. The Dipterous parasites of the gypsy moth and of the brown-tail moth are all members of this family, and will frequently be referred to as the Tachinid parasites, in contradistinction to the Hymenopterous parasites.

The Tachinid parasites, as a class, differ markedly in their manner of life from the Hymenopterous, but not all of them to quite the extent of the one under consideration (Fig. 10). It attacks the gypsy moth during several of the caterpillar stages, but instead of depositing its eggs within the body of the host, they are deposited upon leaves of trees infested by the caterpillars. They are exceedingly minute, black and shining, and one fly can lay many thousands. When eaten by a caterpillar big enough not to crush them in the process they hatch almost immediately into tiny maggots, which pierce the walls of the alimentary canal and lodge themselves in the fatty tissue of the caterpillar's body. They grow slowly, and invariably, if parasitism is successful, the caterpillar pupates. When the moth would have been about ready to issue, had the pupa been healthy, the Blepharipa maggot (Fig. 11) reaches maturity and works its way out of the now empty shell. It then drops to the earth and burrowing its way several inches below the surface, transforms to a puparium (Fig. 12), an oval, dark body, formed of the hardened skin of the larva, and containing the true pupa. This pupa remains unchanged during the winter, and produces the perfect fly in the late spring following.

Blepharipa is a very important parasite of the gypsy moth in Europe, and in western Europe appears to be very much more destructive than does the Glyptapanteles. It is represented in Japan by another very similar species (*Crossocosmia* sp.), the adults of which have not yet been reared at the laboratory.

The difficulties which have stood in the way of the successful introduction of this parasite into America have been different from any that have hindered the work with any other species. Importation of the full-grown caterpillars or freshly formed pupæ of the gypsy moth resulted in 1905 in securing a considerable number, several hundred at least, of the hibernating puparia, but not a single fly issued the following year. The cause was not obvious at the time, but was later determined to be due to the drying up of the pupæ within the puparium. Death did not immediately ensue, but eventually the fly would die when it was nearly ready to issue. A great many different methods of hibernating these puparia have been attempted, and with very variable but uniformly unsatisfactory results. During the winter of 1907–08 the puparia were kept in moist earth, and a 10 per cent. emergence from a total of 5,000 was secured. The year before it was less, hardly equalling 3 per cent., and the year following much less, hardly amounting to 1 per cent. These tremendous losses were unexplained until the summer of 1909, when large numbers of gypsy caterpillars were received in a living condition from Hyeres, France, through the magnificent efforts of M. René Oberthür of Rennes, and as a direct result of Dr. Howard's trip to Europe that year. (Plate II.) They came in better shape, in many respects, than any other similar lot of material ever received, having been shipped in cold storage on fast transatlantic liners.

For the first time since the inception of the work, large numbers of living pupæ containing the immature maggots of the parasites were received at the laboratory, and it was possible to allow the formation of the puparia under natural conditions in the earth. Each preceding year the maggots had reached their maturity, and formed, or attempted to form, puparia in the boxes in transit. They were often injured, and the puparia were always thoroughly dried when received.

A very large number of the parasites were secured in this manner (25,000, as a conservative estimate), and several thousands of the maggots were allowed to enter the earth in the open in forests infested by the gypsy moth. Examination has demonstrated the fact that these maggots pupated in a perfectly natural manner, and the condition of the pupæ at the present time is far and away more satisfactory than it has ever been before at this season of the year. It is almost impossible to conceive of conditions which will prevent the emergence of these flies in large numbers in the open the coming spring.

The remainder of the maggots were allowed to go into the earth in a variety of containers, principally sunken wire screen cages in the laboratory grounds. They, as well as those in the open, are in the best of condition, and it will be a severe disappointment if a large number of the flies are not reared and colonized, as a result.

The parasite was colonized as adults in small numbers and under satisfactory conditions in the spring of 1907, and in somewhat larger numbers in 1908. No results have been secured to date, nor are immediate results expected from these early colonies. The fly is very strong, and it is to be expected that it will fly for long distances during the considerable period of its activity in the spring. Unlike Glyptapanteles, Schedius, etc., it is not ready to deposit its eggs for something like three weeks after it issues in the spring, and during this time it is likely to traverse considerable distances. It is a source of great regret that it has not been liberated in large numbers much earlier in the course of the work; but it was not until after numerous experiments had been made, through which it was hoped to remedy the obvious defects in methods of importation and handling, and all modifications proven to be useless, that the extraordinary methods of last season were adopted. There is not a single other one amongst the numerous species of

Tachinid parasites, except the Japanese Crossocosmia, which is nearly so difficult to handle.

Multiplication of this parasite in the open, under favorable conditions, which it is believed the present season offers, ought to be exceedingly rapid. As in so many other instances, the year to come is crucial, and will likely demonstrate the ability of this species to become Americanized.

Success with Blepharipa, and its rapid acclimatization in America, is looked for more especially on account of the close correlation which exists between the parasite and host. Like Anastatus, this correlation is perfect, and the parasite is able to continue its existence from year's end to year's end, independent of any other insect. This, in connection with its extraordinary powers of multiplication, make it one of the most promising of the parasites studied at the laboratory, and perhaps the most promising of all.

Compsilura concinnata.

Only a very few of the introduced parasites are equally important as enemies of both the gypsy moth and the brown-tail moth, although a number of them are known to attack both to a varying degree. One of the few which are important enemies of both is Compsilura, a Tachinid fly like Blepharipa, but differing from that species in a great many important particulars. Instead of depositing eggs on the foliage, to be eaten by the caterpillars, the eggs hatch in the body of the parent female, and the minute maggots are thrust beneath the skin of the host after a fashion somewhat comparable to the manner in which Glyptapanteles deposits its eggs in the active caterpillars. Usually only one parasite develops in one host.

The maggots begin to feed at once, and in a very short time (less than two weeks in the summer) are full fed, and have caused the death of the host caterpillar. They then work their way outside of its body, drop to the earth and transform to puparia, from which shortly after the adult flies issue.

Since the parasite has been secured in both brown-tail and gypsy moth parasite importations, the numbers which have been received and liberated have been considerable. The first colonies were planted in 1906, and in each year since, but particularly in 1909, new colonies have been located in various parts of eastern Massachusetts. There is no better method for the recovery of the parasite from the field than the collection of gypsy or brown-tail caterpillars and their confinement in cages, where they can be fed, and where the parasite can be secured in case it is present and emerges. This is a tedious process, involves a large amount of labor, and in the case of the brown-tail caterpillars entails much discomfort in its execution; and attempts to determine the distribution of the parasite in the field have not been as thorough as it is intended that they shall be in 1910. Nevertheless, it was recovered from the field upon several occasions in the course of the summer of 1909, and there seems not to be any question that it is thoroughly established and widely distributed in Massachusetts at the present time. Its rate of increase, if the widespread distribution is taken into account, is wholly satisfactory, and, as indicated by the field collections, is as great as of Calosoma and perhaps as of Monodontomerus. It must be remembered, in this connection, that there is no simple means of determining its distribution, as is the case with both of the other species mentioned; and furthermore, that, although it was liberated in 1906, it was not until so late in the season as to make a generation upon the gypsy or brown-tail caterpillars improbable during that year. It was not until 1907 that it can be considered as having had its first good opportunity for reproduction in America, and the fact that it was found to be generally distributed the third season in the field is indicative of a particularly satisfactory progress.

It is not a very important parasite of either the gypsy or the brown-tail moth in Europe. It has never been received from Japan, and it is not expected that it will become of more than relatively minor importance in either connection here, as compared with Blepharipa and Glyptapanteles. At the same time, it has points in its favor not possessed by any other parasite, notably, its ability to pass one generation upon the brown-tail caterpillars and another immediately after upon those of the gypsy; and it is likely to gain in effectiveness, in this manner, a part of what it loses through its probable inability to complete its seasonal cycle without the assistance of an alternate native host. It is very democratic in its choice of hosts, and has been reared in the laboratory from a considerable variety of native caterpillars, including such common species as the fall web worm and the Datana caterpillars, which are frequently so abundant upon various trees and shrubs in the fall.

Tachina larvarum and *Tricholyga grandis.*

These two species of Tachinid parasites are exceedingly similar in many respects and are so difficult to separate in their varíous stages as to have been confused under the name of *Tachina larvarum* during the first three years of the work. On this account, considerable confusion exists concerning the early history of both in America.

Tachina (Fig. 13), like Compsilura, is a parasite of both the brown-tail and the gypsy caterpillars, while Tricholyga is principally confined to the last-mentioned in its host relations. Both deposit large flattened eggs upon the body of the larger caterpillars, and the minute maggots hatching from these eggs burrow into the body of their host, where they grow rapidly. The larva of Tachina usually leaves its host and completes its transformations upon or just beneath the surface of the earth. That of Tricholyga may do this, or it may remain attached to the host and never drop to the ground at all. Both species usually kill the host caterpillars before pupation, but not always.

Several thousands of one or both species were liberated in various localities in 1906 and 1907. Both were colonized in small numbers in 1908, and in very large numbers in 1909. It was not known that either species had established itself until late in the summer of 1909, when Tricholyga was recovered from the field as a parasite of the gypsy moth from the near vicinity of a very small and unsatisfactory colony of the year before. There seems to be every reason to believe that it has succeeded thoroughly in establishing itself, and that it is a mere matter of time until it shall become so common as to be of active assistance in the control of the gypsy moth.

The Tachina, strangely enough, is scarcely distinguishable as an adult, or in any other way than by its behavior as a gypsy moth parasite, from a native American species which has upon rare occasions been reared as a parasite of the gypsy moth. The native species is probably the one which deposits its conspicuous

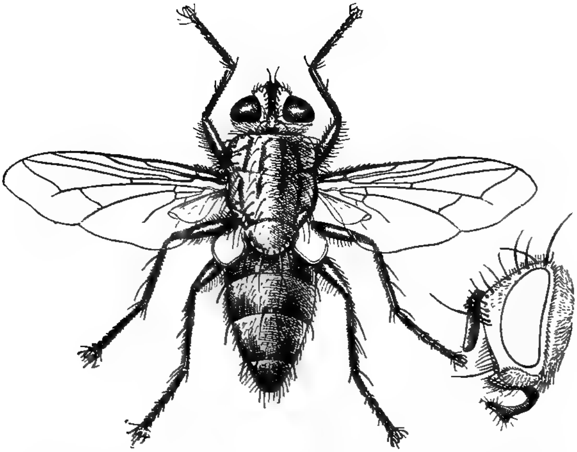


FIG. 13. — *Tachina larvarum:* European parasite of gypsy and brown-tail moth caterpillars, adult, enlarged.

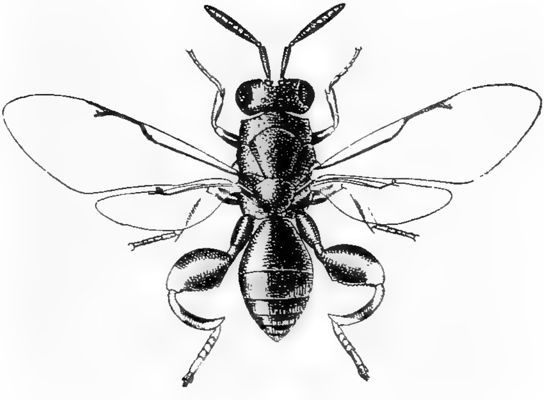


FIG. 14. — *Chalcis flavipes:* European parasite of gypsy moth pupæ, adult, greatly enlarged.

white eggs upon the larger caterpillars of the gypsy moth in certain localities each year so abundantly as periodically to attract attention; but the identity of these eggs cannot be determined, since the maggots which hatch from them rarely go through to maturity. The reasons for this extraordinary state of affairs have not been accurately determined, but in some way the caterpillars of the introduced insect are not fitted to the needs of the maggots of the native parasite.

It has been stated that the native species occasionally completes its growth and transformations upon the gypsy moth, and, since it is impracticable to separate the adults with certainty, there will be no way of following the progress of the imported species in America until it shall become a great deal more common than the native in this connection. It is unquestionably too soon to look for such conditions at the present time, but it is rather confidently expected that within a few years *Tachina larvarum* will become an efficient link in the sequence of parasites which it is hoped to establish.

There is a species of Tachina in Japan, indistinguishable in habit from the European species, and apparently rather more effective. The adults are different, however, and quite easily distinguished from either the American or the European. A small number have been liberated, and it is possible that they will be heard from in the future. It is also expected that a larger number will be imported and liberated the coming season, so that, if the European species for any reason should fail to come up to expectations, the position which it might otherwise occupy will not remain vacant.

Zygobothria gilva and *Carcelia gnava.*

Through the efforts of M. Réné Oberthür of Rennes, very large shipments of gypsy caterpillars and pupæ were received from France in 1909 in much better condition than any considerable shipments ever received before. Largely because of the satisfactory condition of the material on receipt, and partly because the two parasites named above are more common in the Mediterranean region than in northern or central Europe, several thousands of each were imported and colonized under the happy circumstances which accompanied nearly all of the colonizations in 1909. Both had been received before, and both had been colonized, but in insignificant quantities and under conditions which left much to be desired. It is considered, therefore, that the first satisfactory and possibly the first effective colonization of these parasites was accomplished last year.

Both are Tachinids, and similar in many respects to Tachina, Compsilura, etc., but differ from all others and from each other in many minor particulars in their life and habits. In relative importance, as determined by the frequency of their occurrence abroad, they are about equal in rank, and compare favorably in France with any other Tachinid parasites except Blepharipa.

It is hoped that both will establish themselves in America, but their ability to do so remains to be proven, and it is hardly to be expected that either will be recovered before 1911 or 1912, unless some of the earlier and relatively very unsatisfactory colonizations should have resulted more favorably than is now believed to be the case.

PARASITES OF THE PUPA.

Theronia sp.

There are at least 10 species of large, wasp-like parasites which attack the freshly formed pupæ of the gypsy moth, and the caterpillars just previous to their transformation, and which belong to the genera Pimpla and Theronia. All of them are very general in their host relations, and will attack the pupæ of almost any moth which they encounter under the proper conditions; but none of them, with the exception of the several varieties or species of the genus Theronia, have ever occurred so abundantly in any lots of imported gypsy pupæ as to justify a position among the important parasites of the gypsy moth. As parasites of the brown-tail, the several species of Pimpla are quite effective both in Europe and America; and Theronia is also a brown-tail parasite, but of relatively less importance.

There are three species or varieties of Theronia, inhabiting respectively Europe, Japan and America, and all are very similar in appearance and habits. The American species, *Theronia fulvescens,* appears to have reached its maximum effectiveness

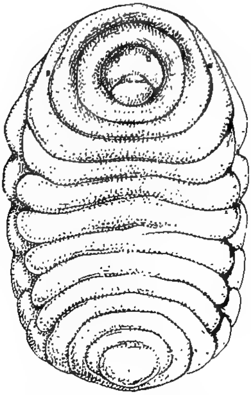


FIG. 15.—Chalcis: full-grown larva from gypsy moth pupa, greatly enlarged.

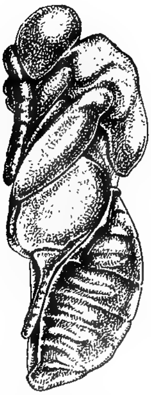


FIG. 16.—Chalcis: pupa from gypsy moth pupa, greatly enlarged.

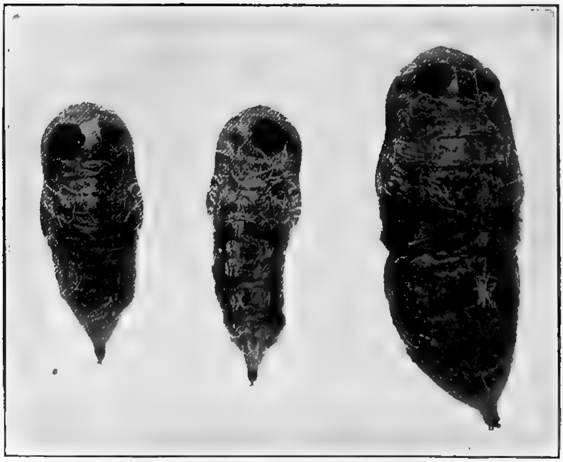


FIG. 17.—Chalcis: gypsy moth pupæ, showing exit hole of the parasite, enlarged.

in America, and without exceeding in this respect the Japanese or the European species in their respective countries. A few of the European *Theronia atalantæ* have been liberated in America, but nothing more is expected of it than of *Theronia fulvescens;* and, as a matter of fact, it will be difficult to determine whether it is established or not, owing to the very close resemblance between the two.

Theronia will help a little in the ultimate control of the gypsy moth in America, but it is not to be expected that it will ever become of greater efficiency than it is at present. It is generally distributed throughout the infested area.

Chalcis flavipes.

One of the most effective parasites of the tussock moth in certain more southern localities is a native species of Chalcis (Fig. 14) which is not very common in any connection in New England. If, as is altogether probable, the gypsy moth extends its southern distribution into the range of Chalcis as a common parasite, it is not at all unlikely that it will be attacked by it.

In southern Europe and in Japan are other species of Chalcis similar to the native species in appearance and habits, and sometimes quite effective parasites of the pupæ of the gypsy moth. They are always solitary, and notwithstanding that there is substance enough in an average gypsy pupa to nourish several individuals, there is no record of more than one ever emerging from one host. The eggs are deposited in the freshly formed pupa, and apparently the individual host is open to attack for a period of only about three days in the course of its life. The larva (Fig. 15) feeds upon as much of the contents of the pupal shell as it desires, and then transforms to a pupa (Fig. 16). The adult emerges later through a large, ragged hole gnawed through the pupal shell. (Fig. 17.)

The European species, *Chalcis flavipes,* was imported in some numbers in 1905, but at that time was supposed to be an enemy of the Tachinids which were primary parasites of the moth, and none were liberated. In 1906 and 1907 none were received, and no opportunity arose to investigate the relations existing between the moth and the parasite. It was not known that it was so closely confined in its geographical distribution at that time, and since no gypsy moth pupæ were received in good condition from any of the Italian or French collectors, its importance was not recognized.

In 1908, for the first time since 1905, a quantity of gypsy moth pupæ was received from Italy, through the courtesy of Professor Leonardi of the School of Agriculture, Portici, and from them quite large numbers of the parasite were reared. At first, with the recorded secondary parasitism of the species in mind, considerable care was exercised to prevent the escape of any of the specimens until their true relation to the gypsy moth should be established. At last, after a rather tedious series of microscopic studies, supplemented by dissections of the parasitized pupæ, it was definitely demonstrated that the Chalcis which issued from the Tachinid puparia were different from those which came from pupa direct; in other words, there were several species of the genus Chalcis, closely resembling each other in their appearance, but differing entirely in their habits. One of them was, beyond further dispute, a primary parasite of the gypsy moth, and was immediately liberated in the field, while the others were destroyed as fast as secured.

In 1909 a few more were received in importations of gypsy pupæ from Italy and France, and another small colony was established. It is known definitely that reproduction in the field followed immediately after, but there is insufficient assurance that the species is acclimatized in America, since it has not been recovered a full year after its colonization. If it disperses as rapidly as do most of the parasites, it will be some years before it is again recovered as the result of the last summer's colonization. During this period it is hoped that additional importations will make it possible to establish larger and stronger colonies of what, if it can exist here, is very likely to become a parasite of some importance.

In both 1908 and 1909 *Chalcis flavipes* was carried through all of its transformations in gypsy moth pupæ in the laboratory; and, but for the fact that a supply of host pupæ cannot be provided except during a very limited season each year, it would be practicable to institute propagation work similar to that which has been so successful with Schedius and Calosoma. Only about one month is required for the complete life cycle from

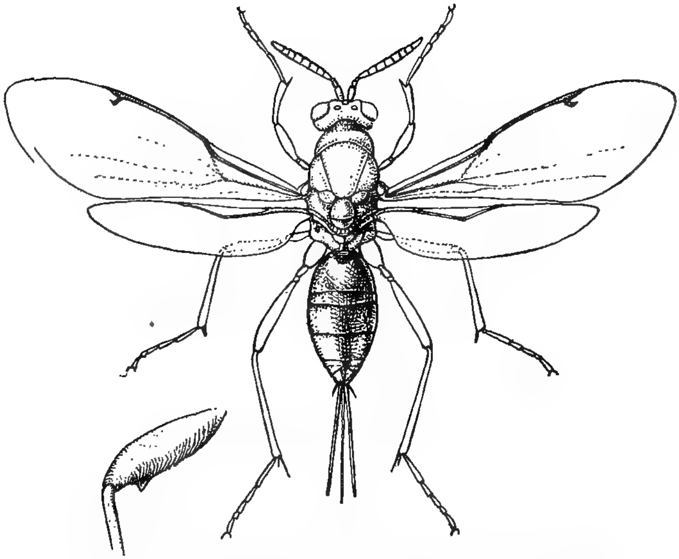


FIG. 18.—*Monodontomerus aereus:* European parasite of gypsy and brown-tail moth pupæ, adult female, greatly enlarged.

egg to adult. It is very probable that the adults live for a long time, like those of Monodontomerus, and they may hibernate.

Monodontomerus aereus.

The females (Fig. 18) deposit their eggs (Fig. 19) in the freshly formed pupæ of the gypsy moth and of the brown-tail moth, several in each individual host. The larvæ (Fig. 20) feed and subsequently undergo all of their transformations within the pupal shell, of which they usually consume the entire contents. (Fig. 21.) A little later than the time when the moth would have issued, had the parasitized pupa remained healthy, the Monodontomerus adults escape through a small hole in the dried pupal shell. (Fig. 22.) From 5 or 6 to 15 or 20 come from each. The males die soon after, but the females live all winter, and are not able to deposit eggs for another generation until the summer following. When cold weather approaches they seek the shelter afforded by the hibernating webs of the brown-tail caterpillars, and remain well protected in the silken chambers during the winter. They come forth in the spring as soon as the weather becomes warm enough to stir them into activity, and in the course of the period intervening between their resumption of activity and the pupation of the brown-tail and gypsy, they develop their eggs and are ready for the attack.

A considerable number of the adults of this parasite, all, without exception, fertilized females, issued from the large number of brown-tail hibernating nests which were imported from various European countries during the winter of 1905–06. A part were given their freedom in the spring, but as it was soon found that the species were not in any way an enemy of the hibernating brown-tail caterpillars, and as their parasitism of the pupæ of the gypsy moth and brown-tail moth was not indicated at that time, their liberation was discontinued. In 1906 and 1907 small numbers were reared from imported cocoon masses of brown-tail, but under conditions which told nothing concerning their host relations. Upon several occasions small numbers have been reared from the puparia of Tachinid parasites of the gypsy moth, and it was feared that the parasite might prove to be habitually secondary, instead of primary.

Like Chalcis, Monodontomerus is more common in southern

Europe, and the small quantities of gypsy and brown-tail pupæ which were received in 1906 and 1907 from those countries where it was most abundant made any attempts to investigate its life and habits difficult of execution. The females would never evince any interest in gypsy or brown-tail pupæ in the laboratory, and all of the many reproduction experiments which were made failed utterly. This was subsequently found to be due to the fact that their eggs were undeveloped, and it was not until a careful series of microscopic dissections were made that this insuperable obstacle to success was discovered.

In 1908 the same importation of gypsy moth pupæ from Italy which served to establish the host relations of Chalcis served also to establish the primary character of the parasitism by Monodontomerus. It was reared from the gypsy moth pupæ direct, and in such numbers as to indicate that it was a parasite of considerable importance; and great regret was felt that it had not been liberated in larger numbers upon the first opportunity. It was hardly considered probable at that time that the small number liberated during the early spring of 1906 would succeed in establishing themselves.

In the winter of 1908–09, large numbers of the hibernating nests of brown-tail were collected from various localities, as they had been each winter since the beginning of the work, and from these nests issued a very few hibernating females of Monodontomerus, exactly as they had previously issued from nests similarly collected in Europe. The circumstance was as unexpected as it was gratifying, and indicated that the parasite had multiplied rapidly in the field, because similar collections of even larger quantities of brown-tail nests had not produced the parasite the year before. Steps were immediately taken to determine the distribution of the parasite, and the surprise was greater when it was discovered to be sparingly but generally distributed over an area of approximately 500 square miles, extending in nearly every direction, but farthest to the west, from the original point of liberation.

In the summer of 1909, when the proper season had arrived, it was recovered for the first time as a parasite of the gypsy moth in the field. Although it was not very common, it was found to be generally distributed, exactly as indicated by the collections

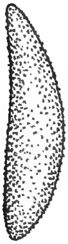


FIG. 19.—Monodontomerus: egg, greatly enlarged.

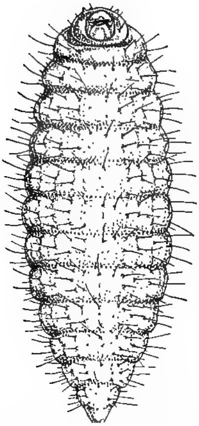


FIG. 20.—Monodontomerus: larva from gypsy moth pupa, greatly enlarged.

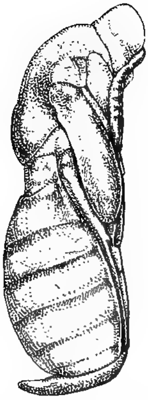


FIG. 21.—Monodontomerus: pupa from gypsy moth pupa, greatly enlarged.

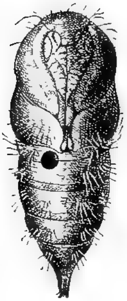


FIG. 22.—Monodontomerus: gypsy moth pupa, showing exit hole left by parasite, greatly enlarged.

from brown-tail nests the winter before. The percentage of the gypsy pupæ destroyed was negligible; but the fact remained that the parasite was on the increase, since exactly the same methods employed in previous years had produced no such results.

Great curiosity was felt as to the probable character of the results of winter work in the recovery of the hibernating females in the winter nests of brown-tails in the fall of 1909, as this would provide the first opportunity to determine the rate of annual increase and of dispersion. The work was begun as soon as practicable, and, while the results are not yet complete, they are more favorable than was at any time anticipated. In brief, the insect is now known to be distributed over an area of approximately 3,000 square miles. Every portion of the Commonwealth north and east of Boston to the New Hampshire line, and as far west and southwest as Leominster, Shirley and Dover, is included in this territory. It is certain to be in New Hampshire, but to date none have been received from that State, and the western limits of its distribution have not been determined.

Everywhere in the area which was not included in its known distribution last year it is about as common as it was in any place the winter before. Within the limits of the territory in which it was known to occur a year ago it has increased at least twenty-five-fold during the year. At this rate, if unchecked, it would be abundant enough to destroy *all* of the gypsy and brown-tail pupæ in three years more. Since this, for various reasons, is highly improbable, it is likely that it will reach its maximum effectiveness within the centrally infested areas by that time. Judging from the best which it is known to do abroad, this will be the destruction of something like one-fourth of the gypsy and brown-tail pupæ. It is not abroad, and cannot be expected to become in America a parasite of as great importance as Glyptapanteles or Blepharipa, provided these species become as thoroughly acclimatized; but it promises to become a very valuable parasite, occupying, as it does, a position in the sequence of parasites which would otherwise be vacant except for the ineffective Theronia or the less certainly efficient Chalcis.

PROGRESS OF THE PARASITES IN MASSACHUSETTS.

Before it is possible accurately to predict the progress of an insect in a new country, it is necessary to know, first, the average rate of increase under the new conditions; and, second, the average rate of dispersion. Neither may be determined otherwise than by actual observation in the field. In the countries to which the insect in question is native, the rate of increase is balanced more or less perfectly, and, although it always fluctuates somewhat in relative abundance from one year to another, there is no permanent gain or loss. The dispersion of an insect in a country where it is native and generally distributed is impossible of determination; the progeny of any given parent or of the parents within a given area are at once confused with the progeny of parents in any part of the surrounding country into which they may chance to spread.

The introduction of an insect into a new country is usually followed by a steady increase, which is sustained until it has established a balance with the native insects; or by a steady decrease, which results in its final extinction.

There are a few instances on record in which the progress of an introduced insect has followed neither path. The Chinese lady-bird (*Chilchorus similis*) was introduced into Georgia in 1902 as an enemy of the San José scale, and for one year increased at a very rapid rate, and spread over a considerable territory from the point where it was liberated. It passed the first winter successfully, and for a time bade fair to become so numerous as to be of valuable assistance in the fight against this scale; but in 1904 its numbers showed a decided decrease, and at the present time it appears not to be at all common. The causes for this are very obscure, and no satisfactory explanation has ever been advanced.

The history of the Oriental moth in Boston, where a few years ago it appeared to have become firmly established, is another case in point. At the present time it is far from common, and it is very possible that eventually it will become extinct.

It will never be known how many insects have been introduced into America from abroad, but the number is undoubtedly far in excess of those which have become temporarily or permanently abundant enough to attract attention.

It has never been expected that all of the parasites and predatory enemies of the gypsy and brown-tail moths which have been introduced into Massachusetts would continue to exist here. It has always been expected that certain of them would do so, and the only cause for uneasiness as to the ultimate success of the work has been the fear that not enough different kinds of parasites could be secured for colonization, or, if colonized, that not enough to form a natural and effective parasitic sequence would be able to continue to exist. At the present time there is no parasite of the gypsy moth, and only one or more of the brown-tail, of which it can be said that the progress is unsatisfactory. Just what the progress is, or whether there is any actual progress, is not known in every case; but, as will be shown, it may be very satisfactory, and at the same time inconspicuous.

In the beginning it was expected that increase, if it followed colonization, would be rapid; but it was not thought that many of the several species would be likely to fly very far from the point of liberation until they had increased for several generations. Had these expectations been fulfilled, practical results would have been apparent, locally, within three or four years.

So far as it is possible now to state, the rate of multiplication has generally been gratifyingly rapid; but it has been accompanied by a rate of dispersion so much greater than was expected as to materially change the aspect of the situation. It is now evident that, if success follows the work of parasite introduction, the parasites will become practically effective over a considerable portion of the infested area, and possibly throughout its whole extent, at about the same time.

In order better to illustrate this point, a theoretical example may be taken of an insect introduced into a new country, where it increases at the rate of twenty-five-fold annually, and spreads from the point of liberation at the rate of about 10 miles annually. It is supposed that 1,000 individuals are liberated in a territory where they can be spread in every direction, and where their increase will be unhampered for a period of six years.

Lest any one should think that the figures and diagrams as given are fanciful, and the result of pure speculation, it is well to state in the beginning that they represent, as accurately as the available information will permit, the progress of Monodontomerus in the field. The territory covered is not quite as extensive as indicated by the first diagram, owing to the fact that a large part of it is, or would be, open sea; but the recovery of the parasite from the field indicates that it has spread at a rate of approximately 10 miles annually to the west and north, and that its increase, which was about twenty-five-fold during the summer of 1909, has been maintained at that rate since its liberation. It is not known exactly how many of the parasites were liberated originally, the notes which were made at that time apparently having been lost. Tentatively, the figures are set at 1,000.

The rate of dispersion, provided it was dependent upon the activities of the insect, and not upon chance or accidental agencies, would be about as rapid during the first year from a colony of 1,000 as though it were very abundant. The territory covered by the insect during the six years would therefore be represented by a series of six concentric circles, the smallest of which would have a radius of 10 miles, and each of the others of multiples of 10 up to 60. The area given in acres, and for convenience sake in round numbers, over which the insect would range each year from the first to the sixth, respectively, would be as indicated in Diagram I.

Increase numerically, at the rate of twenty-five-fold annually, would be at a very much more rapid rate, and is indicated by the several squares in Diagram II. It would be impossible to illustrate this increase diagrammatically for the entire six years without the use of a large chart, because the square which would indicate the number of the insects which would result from the sixth year's increase would have sides between 3 and 4 feet long. The figures for six years would be: —

1906,	1,000
1907,	25,000
1908,	625,000
1909,	15,625,000
1910,	390,625,000
1911,	9,725,625,000

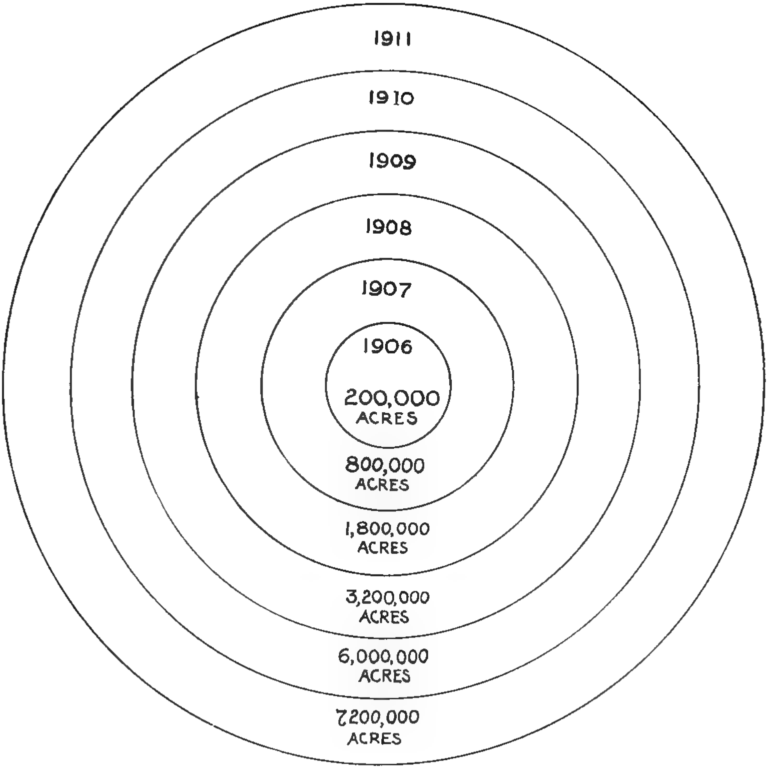


DIAGRAM I.—Illustrating the dispersion of an introduced insect for six years, at the rate of approximately ten miles per year.

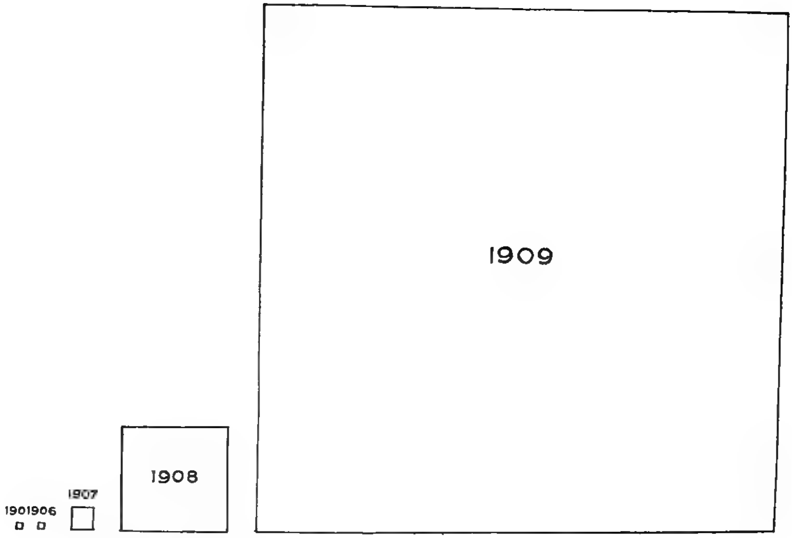
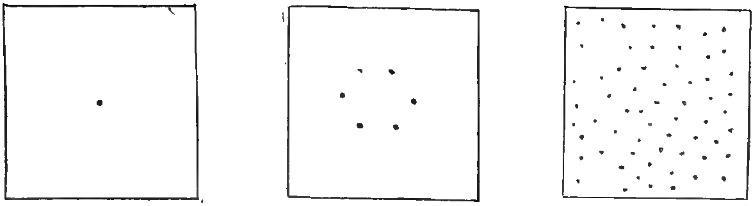


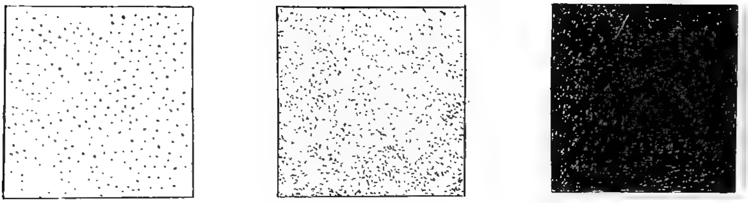
DIAGRAM II. — Illustrating the numerical increase of an introduced insect for four years, at the rate of twenty-five-fold each year.



1906.
1 individual to 200 acres.

1907.
5 individuals to 200 acres.

1908.
69 individuals to 200 acres.



1909.
976 individuals to 200 acres.

1910.
15,625 individuals to 200 acres.

1911.
270,156 individuals to 200 acres.

Diagram III.—Illustrating the increase in average abundance of an introduced insect which disperses as indicated by Diagram I. and increases at the rate indicated by Diagram II.

Increase in the average abundance of the insect from year to year over the area included in its range would be comparatively slow at first, but would later become much more rapid, on account of the rate of increase being so much greater than that of dispersion. An attempt has been made to illustrate it in Diagram III., in which each square represents an area of 200 acres. The number of the insects (Monodontomerus in this instance) which are to be found within a territory of this extent is indicated by the black dots. It becomes impossible to crowd a sufficiently large number into the limited space available to indicate accurately the proportionate abundance which will result in 1910 and 1911, if the rate of increase continues without diminution.

The parasites are generally very inconspicuous, and when not common are difficult to find. Monodontomerus, as has been stated, is particularly easy to find, owing to its hibernating habits; and it is partly on this account that so much is known of its progress. The only methods which may be employed for the recovery of the most of them is the collection of a quantity of the caterpillars or pupæ of the gypsy moth, which are confined in the proper form of cage in the laboratory until the parasites issue from the affected individuals after destroying them. To collect all of the gypsy caterpillars or pupæ over a territory as large as 1 acre is out of the question when the insect is abundant. It is therefore impracticable to follow systematically the progress of an insect which would be so uncommon as to be represented by only a single individual in an area of this extent. It is small wonder that no trace of certain of the parasites which have been liberated has been found during the first few years following.

It was not until the summer of 1909, the fourth after its establishment, that Monodontomerus was first recovered as a parasite of the gypsy moth in the field; and if a parasite can increase at such a rate and remain unnoticed for three years, there is good foundation for hoping that other species may be doing as well.

The Calosoma beetles, which were also liberated for the first time in 1906, in time to attack the gypsy moth caterpillars that year, have ever since increased at a less rapid but at the same time a very satisfactory rate. Their rate of dispersion is also much less, and probably does not exceed a mile or two per year.

It will be several years before they will reach the abundance at present held by Monodontomerus.

These two insects, Monodontomerus and Calosoma,[1] were the only enemies of the gypsy moth which were liberated in 1906 in time to attack the gypsy caterpillars that year. A number of other parasites were given their freedom during the late summer or fall, after the caterpillar season was nearly or quite over, and the first opportunity which they had to attack the gypsy or the brown-tail caterpillars was in the year following. Of these parasites, one, Compsilura, has been recovered in the past summer in numbers in every way as large as could be expected, if its rate of dispersion is as rapid as that of Monodontomerus. A greater rapidity of dispersion and multiplication, sustained over a period of years, has not been expected of any of the introduced insects.

WHEN WILL THE PARASITES BECOME EFFECTIVE?

This question, which has been asked so frequently, has always been avoided, especially since it became apparent that the dispersion of the parasites was going on at an unexpectedly rapid rate, making their recovery difficult except in the immediate vicinity of the colony and immediately after colonization. It was obviously impossible, under such circumstances, to determine what their actual progress was; and the only results which were apparent to those in charge of the work were so technical in their nature as to be of little significance to any one not thoroughly familiar with entomology.

During the past few months considerable data have been accumulated, uniformly satisfactory in character, which bears upon the rate of dispersion or of multiplication of certain of the parasites. It is very insufficient, but if it is reliable, and if the progress of the first among the parasites and predators to be liberated may be taken as a criterion of what is to be expected of the others, it is possible to make a fair estimate of the length of time required for the parasites to become sufficiently abundant and so generally distributed as to bring about an effective natural control of the gypsy moth. The different species differ in so many particulars, however, as to make such an estimate at the present time largely speculative.

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[1] *Calosoma inquisitor*, another predaceous beetle, was also liberated in 1906, but in rather small and unsatisfactory numbers. It has not been recovered.

In Table 4 are listed all of the parasites of the gypsy moth which have been liberated in America under conditions in every way satisfactory. The dates when the first satisfactory colony of each was established will be found in the second column. When, as so frequently happened, the parasite was secured too late in the season to make its attack upon the caterpillars possible until another year, the circumstance is indicated in the third column. The fourth column indicates when the parasite was first recovered from the immediate vicinity, and the fifth when it was found to be generally distributed. On the supposition that the progress of the parasites later liberated will be comparable with that of the earlier, the dates when each of the species listed can be expected to become effective in their respective rôles of egg, caterpillar or pupa parasites, are indicated in the last column.

TABLE 4. — *Showing Date of Liberation and Subsequent Progress of the Parasites of the Gypsy Moth in Massachusetts.*

PARASITES.	First liberated under Satisfactory Conditions.	First Opportunity to reproduce as a Parasite or Enemy of the Gypsy Moth.	First recovered from Immediate Vicinity of Colony.	First recovered at a Distance from Colony Site.	Will probably become Effective.
Theronia fulvescens,[1]			–		
Monodontomerus aereus,	1906	1906	–[2]	1909	1911
Calosoma sycophanta,	1906	1906	1907	1909	1911
Compsilura concinnata,	1906	1907	1907	1909	1912
Tachina larvarum,	1906	1907	–[3]	–[3]	1912
Tricholyga grandis,[4]	1906 ?	1907 ?	1909 ?	1909 ?	1912 ?
Glyptapanteles fulvipes,	1908	1909	1909		1914
Anastatus bifasciatus,	1909	1909	1909		– ?
Schedius kuvanæ,	1909	1909	1909		1912
Chalcis flavipes,	1909	1909	1909		1915
Blepharipa scutellata,	1909	1910			1916
Zygobothria gilva,	1909	1910			1916
Carcelia gnava,	1909	1910	–		1916

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[1] A native parasite, of slight relative importance.

[2] First recovered at a distance from colony.

[3] Adults indistinguishable from a native species, which is rarely parasitic on the gypsy moth.

[4] It is not known positively when Tricholyga was first liberated, owing to its very close resemblance, in appearance of adult, to Tachina. The recovery from the field in 1909 may have been the result of colonization in 1908, or equally well of that of earlier years.

Earlier in this paper an attempt was made to point out the necessity of establishing a sufficient number of parasites to form a natural sequence, which would attack each stage of the moth, from egg to pupa. Every parasite necessary to make an effective sequence is represented in the list given, but there are several, including at least one of considerable importance (*Blepharipa scutellata*), which may not become effective before 1916. Since the chain is no stronger than its weakest link, the sequence of parasites will not become fully effective until each necessary component of the sequence has reached the necessary abundance. It will be 1916 before the complete control of the gypsy moth in New England can reasonably be expected, and, unless the writer is mistaken, this control, when it is effected, will be general over all of the infested area.

THE WORK IN 1910.

The year 1910 will be crucial in one respect, since it will give ample opportunity to prove or disprove a number of the premises which have been used as a basis for the above calculation. It ought to be possible to follow the progress of several parasites very exactly, and their progress must be proportionate to the distance which they must travel if they are to become effective in their respective rôles by the time set. Should the actual developments of this season fall short of what is considered to be a necessary amount of progress, the disappointment of those in charge of the work will be very great.

It is hoped that Monodontomerus will increase at about the same rate which has prevailed in the past, but a slight falling off is rather expected. In like manner increase in the numbers of and in the territory covered by Calosoma ought to be commensurate with the progress of this species during the past year. Compsilura ought to be recovered with ease, and it should be possible to determine more accurately its rate of increase and of dispersion. Tachina ought to be recovered for the first time, and Tricholyga may or may not show decided increase, owing to the doubt which exists concerning its early history in America. It is hardly expected that Glyptapanteles will be found at all. If it were, the circumstance would be more encouraging than anything which has happened: first, because it would allay the doubts which have been felt as to its ability to exist here; and second, because it would indicate an increase beyond what could be reasonably expected. The egg parasites, Anastatus and Schedius, and the Tachinid Blepharipa, must demonstrate their ability to survive the New England winters. It is hardly to be expected that Carcelia, Zygobothria and Chalcis will be recovered. Should any or all of them be found, it would be considered as particularly encouraging.

PARASITES OF THE BROWN-TAIL MOTH.

The brown-tail moth is generally and with justice considered to be the less injurious of the two imported pests, and largely on this account the major part of the space in this bulletin is devoted to the consideration of the gypsy moth and its parasites. It must not be concluded from this, however, that the parasites of the brown-tail moth have been treated with less consideration in the laboratory. They have received their full share of attention, and work upon them, which naturally begins in the winter, at a time when very little can be done on the parasites of the gypsy moth, is largely completed by the end of June, before the larger and more important importations of gypsy moth material are received.

The brown-tail is generally more common and more frequently injurious than the gypsy moth in Europe, and appears to be less completely controlled by its parasites. It is attacked by a greater variety, but more of the species are of distinctly minor importance.

There are at least six parasites native to America which attack the brown-tail moth as freely as the native Theronia attacks the gypsy moth. One of these, Diglochis, is apparently the same as the European *Diglochis omnivorus*. All but one of the remainder are very similar in habit to European species, as may be seen by reference to Table 5.

All of the European parasites known to be of importance abroad have been imported and liberated in some numbers; but in a few instances we have not been able to secure a sufficiently large number to establish strong colonies. Several of the European species, on account of their very close resemblance to American forms which attack the brown-tail in this country, cannot be considered as of much promise; and two (Trichogramma and Pteromalus) have been given every opportunity to prove their worth, but have not responded at all satisfactorily.

There are, however, ten or twelve European parasites different from any known to attack the brown-tail in America, and which include several of great promise, which will be of material assistance in reducing the present prevailing abundance of their host, if they prove adaptable to American conditions.

In Table 5 are listed all of the known parasites of the brown-tail moth which play any considerable part in effecting its control. The names of the native American species are in black-faced type; those of European species which have been imported in satisfactory numbers and colonized under favorable conditions are in Roman type; while those of the European species which have not yet been received under satisfactory conditions are italicized.

Nearly all of the introduced species have been recovered from the field, but not all of them are known to be firmly established. Three of them, Monodontomerus, Tachina and Compsilura, are promising parasites of the gypsy moth also.

TABLE 5. — *Brown-tail Moth.* — *Sequence of Parasites.*

PARASITES.	Egg.	LARVAL STAGES.								PUPAL STAGES.			Adult.
		FALL STAGES.			Winter Stages.	SPRING STAGES.				Pre-pupa.	Fresh.	Old.	
		First.	Second.	Third.		First.	Second.	Third.	Fourth.				
Trichogramma sp.,	⋮▮												
Trichogramma pretiosa,	⋮▮												
Telenomous phalænarum,	⋮▮												
Apanteles viminetorum,				⋮▮	▮	▮							
Meteorus versicolor,				⋮▮ Fall Generation	▮	▮	▮						
							⋮▮ Spring Generation	⋮▮	▮				
Zygobothria nidicola,				⋮▮	▮	▮	▮	▮	▮	▮			
Pteromalus egregius,					⋮▮								
Parexorista cheloniæ,						⋮▮	⋮▮	⋮▮	▮	▮	▮		
Dexodes nigripes,						⋮▮	⋮▮	⋮▮	▮				
Compsilura concinnata,[1]				[1] ⋮		⋮▮	⋮▮	⋮▮	▮				
Eupeleteria magnicornis,							⋮▮	⋮▮	▮	▮			
Zenillia libatrix,							⋮▮	⋮▮	▮	▮	▮		
Pales pavida,							⋮▮	⋮▮	▮	▮	▮		
Tachina larvarum,							⋮▮	⋮▮	⋮▮	▮	▮		
Anomalon exile,							⋮▮	⋮▮	⋮▮	▮	▮	▮	

[1] Attacks young caterpillars before hibernation, but larvæ apparently fail to mature.

TABLE 5.—*Brown-tail Moth.*—*Sequence of Parasites*—Concluded.

PARASITES.	Egg.	LARVAL STAGES.								PUPAL STAGES.			Adult.
		FALL STAGES.			Winter Stages.	SPRING STAGES.				Pre-pupa.	Fresh.	Old.	
		First.	Second.	Third.		First.	Second.	Third.	Fourth.				
Pimpla pedalis,										┄ ━	┄ ━	━	
Pimpla conquisitor,										┄ ━	┄ ━	━	
Pimpla instigator,										┄ ━	┄ ━	━	
Pimpla examinator,										┄ ━	┄ ━	━	
Theronia fulvescens,										┄ ━	┄ ━	━	
Theronia atalantæ,										┄ ━	┄ ━	━	
Monodontomerus aereus,[1]					[1] ━						┄ ━	━	
Diglochis omnivorus,											┄ ━	━	

[1] Adult females hibernate in winter nests.